FFI Norwegian Defence Research Establishment

Sea Mammal Research Unit

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FFI-RAPPORT

Effect of naval sonar exposure on killer whales and humpback whales

– 3S-2023 cruise report

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Summary

3S (Sea mammals and Sonar Safety) is a multidisciplinary and international collaboration studying how naval sonar affects cetaceans. The goal is to gain information necessary to manage the risk to cetaceans without unnecessarily restricting naval sonar activities. One of the objectives of phase 4 of the 3S project (3S4) is to investigate if exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals. Another is to investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration. The 3S-2023 trial was conducted off the coast of Norway in October–November 2023 to collect data to address these research questions. The purpose of this report is to summarize and document the data collected.

The experimental design was based on short- and long-duration CAS and PAS exposures to killer whales and humpback whales using real-time GPS location data of multiple tagged subjects. The sonar source vessel was moved to achieve repeated dose escalations over 8 hours, and responses to the first approach will be compared to subsequent approaches in the analysis. Multiple whales were tagged with suction cup attached mixed-DTAG^{++}, which records high resolution movement and acoustic data and transfers the GPS position of the tagged whales directly to the source vessel. Behavior was recorded for 8 hours before exposure, during the 8 hours long exposure and for 4–6 hours after exposure. In addition, Wildlife Computers SPLASH10-F-333B Limpet tags, which transfer lower resolution data via the Argos satellite, were deployed to record natural diurnal patterns of killer whales and potential responses to sonar of animals further away from the source. In addition to data on animal behavior recorded by the tags, we also collected data on the prey field in the area using echosounder and collected fish samples. Sound speed profiles were collected to understand how the sonar signals propagate in the area.

During the 3S-2023 trial, 13 mixed-DTAG^{++} and 6 satellite Splash tags were deployed to killer whales, and 5 mixed-DTAG^{++} were deployed to humpback whales. Of the 18 mixed-DTAG^{++} deployments, 11 were baseline-only records with durations varying from 5 minutes to 28.3 hours, and 2 were deployments on non-focal animals containing baseline and exposure data. Four long-duration controlled exposure experiments (two CAS and two PAS) on multiple focal animals (4 killer whales and 1 humpback whale) were conducted using direct GPS tracking. The Splash tags collected data on diurnal patterns of killer whales over periods from 1 to 7 weeks. Most tags were deployed to animals feeding around herring fishing vessels using purse seine.

The 3S-2023 trial was a success, although we were hoping to conduct more exposure experiments. However, such long duration exposure experiments have never been conducted before, and any data are highly valuable. We plan to collect more data during a similar trial in 2024. For the 3S-2024 trial, we recommend starting a week later to assure that the fishing fleet is in place when we start. We also have some concerns which need to be addressed about availability and reliability of DTAG core units and availability of a proper CAS source for 2024.

A video showing the activities during the 3S-2023 trial can be seen following this link.

Sammendrag

3S (Sea mammals and Sonar Safety) er et multidisiplinært og internasjonalt samarbeid for å studere effekten av militære sonarer på hval. Målet er å innhente kunnskap som er nødvendig for å redusere risikoen for hvalene uten unødvendige restriksjoner på sonarbruk. Et av målene med fase 4 av 3S-prosjektet (3S4) er å undersøke om eksponering for kontinuerlige aktive sonarsignaler (CAS) fører til andre eller mer alvorlige reaksjoner enn eksponering til konvensjonelle pulsede aktive sonarsignaler (PAS). Et annet mål er å undersøke empirisk om reaksjoner til kortvarige eksponeringer kan brukes til å predikere reaksjoner til eksponeringer som har en mer realistisk operativ varighet. 3S-2023-toktet fant sted utenfor kysten av Norge i oktober–november 2023 og skulle innhente data som adresserer disse spørsmålene. I denne rapporten oppsummerer og dokumenterer vi datainnsamlingen.

Det eksperimentelle designet baserte seg på kortvarige og langvarige CAS- og PAS-eksponeringer på spekkhoggere og knølhval ved hjelp av GPS-sporing i sanntid av flere merkede hvaler samtidig. Sonarfartøyet manøvrerte på en måte som gjorde at vi oppnådde gjentatte doseeskaleringer over 8 timer, og hvalens reaksjon til den første eksponeringen vil bli sammenlignet med den andre eksponeringen i fremtidige analyser. Flere hvaler ble merket med mixed-DTAG++, som registrerer høyoppløselig bevegelsesdata og akustiske data og sender dyrenes GPS-posisjon direkte til sonarfartøyet. Atferden ble registrert over en periode på 8 timer før sonareksponering, under den 8 timer lange eksponeringen og i en periode på 4–6 timer etter eksponeringen. I tillegg ble det brukt Wildlife Computers SPLASH10-F-333B Limpit-merker som sender data med lavere oppløsning via satellitten Argos for å studere dyrenes naturlige døgnrytme og for, om mulig, registrere reaksjoner hos dyr som er lenger unna sonaren. I tillegg til atferdsdata ble det også samlet inn ekkolodd¬registreringer av sildestimer og fiskeprøver av hvalenes byttedyr. Lydhastighetsprofiler ble samlet inn for å kartlegge lydforplantingsforholdene i området.

Under 3S-2023-toktet ble 13 spekkhoggere merket med mixed-DTAG++ og 6 med SPLASH-merker. Fem knølhvaler ble merket med mixed-DTAG++. Av de 18 mixed-DTAG++ som ble satt ut, samlet 11 kun inn grunndata om normalatferdsdata med varighet fra 5 minutter til 28,3 timer, og 2 samlet in data fra dyr som var lenger unna sonarkilden under eksponering. Fire sonareksponeringer med 8 timers varighet (2 CAS og 2 PAS) ble gjennomført på til sammen 5 dyr (4 spekkhoggere og 1 knølhval) ved bruk av direkte GPS-sporing. Splash-merkene samlet inn data fra spekkhoggere over en periode på 1–7 uker. De fleste dyrene ble merket rundt fiskefartøy med ringnot som fisket sild i området.

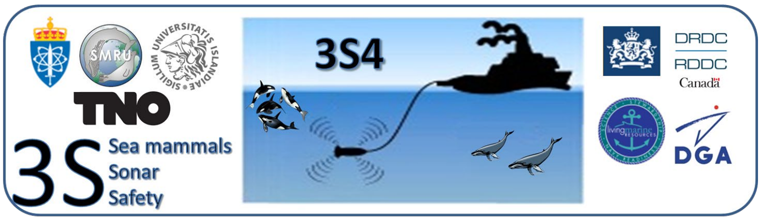
3S-2023-toktet var en suksess, selv om vi hadde håpet å få gjennomført flere eksponeringsforsøk. Slike langvarige eksponeringer har derimot aldri blitt gjennomført før, og de innsamlede dataene er derfor av høy verdi. Vi planlegger et nytt tokt i 2024 og håper da å samle inn mer data. Vi anbefaler at neste års tokt starter en uke senere for å sikre at ringnotflåten er på plass når vi starter. Vi har enkelte bekymringer med tanke på tilgangen på DTAG-sensorer og en tilfredsstillende CAS-kilde til toktet i 2024, og disse bør avklares før neste tokt.

Du kan se en video som viser aktivitetene under 3S-2023-toktet, ved å følge denne linken

Contents

Preface

3S (Sea mammals and Sonar Safety) is a multidisciplinary and international collaboration studying how naval sonar affects cetaceans. The objective is to gain information necessary to effectively manage the risk to cetaceans without unnecessarily restricting naval sonar activities. Phase 4 of the project (3S4) started in 2023 with FFI, TNO, DRDC, Sea Mammal Research Unit and University of Iceland as the main partners. The project is funded by the US Navy Living Marine Resources research program, Defence Research and Development Canada (DRDC), The Dutch Materiel and IT Command (COMMIT) and the French Government Defence procurement and technology agency (DGA).



This report summarizes the achievements of the 3S-2023 sea trial. The purpose of the report is to document the data collected and the target readers are our sponsors and the science team involved in data analysis. This report does not contain higher level analyses and interpretations of the data. Analysis of the data collected is still on-going and will be published in peer-review literature in the coming years.

Horten, March 15. 2024
Petter Kvadsheim
CO 3S-2023

1 Introduction

Modern long-range anti-submarine warfare sonars transmit powerful sound pulses which can have a negative impact on marine mammals. Behavioral response studies (BRS) conducted by research groups on US ranges (the AUTEC, SOCAL and Atlantic BRS projects) (Tyack et al. 2011, Southall et al. 2012, Southall et al. 2019) and in Norway (the previous three phases of the Sea Mammals and Sonar Safety 3S-projects) (Miller et al. 2011, Kvadsheim et al. 2015, Kvadsheim et al. 2021) over the past 10 years have shown large variation in responsiveness between different species, as well as substantial variation within a species depending on the behavioral context of the animals and other factors (Harris et al. 2018). Behavioral responses such as avoidance of the sonar source, cessation of feeding, changes in dive behavior and changes in vocal and social behavior have been observed, and response thresholds quantified. Results from BRS have helped navies to comply with international guidelines for stewardship of the environment, as well as permit procedures and regulations within US and Europe.

All BRS research so far, except the third phase of the 3S-project (Isojunno et al. 2020), have been conducted using pulsed active sonars (PAS), typically transmitting at a 5-10% duty cycle. Recent technological developments imply that, in the near future, naval sonars will have the capability to transmit almost continuously (Continuous Active Sonar, CAS). This technology leads to more continuous illumination of a target and therefore more detection opportunities (van Vossen et al. 2011). In many anti-submarine warfare scenarios, CAS will give a tactical advantage with increased probability of detection, and therefore there is a strong desire within navies to operationalize this technology. This raises imminent questions about the environmental impact of such sonar systems. Robust results from sperm whales indicated that the severity of reduced foraging response is better predicted by ping-by-ping cumulative signal energy than by received sound pressure level (Isojunno et al. 2020), but knowledge from other species is needed. Of particular relevance are species that vocalize in the frequency band of the sonar (e.g., killer whales and humpback whales), since CAS has higher potential for masking biologically important sounds (e.g., conspecific calls).

The biological relevance or severity of behavioral responses depends upon the duration of responses. Behavioral responses that last through the entire duration of a sonar exposure period, or longer, are considered more severe than equivalent responses that cease while the sonar is still transmitting (Miller et al. 2012). A key challenge exists to extrapolate results from the short duration (30-40min) experimental exposures used to date in BRS studies (e.g., Miller et al. 2014, Kvadsheim et al. 2015, 2021) to the typically longer duration operational activities of navies using sonar typically lasting 6-12 hrs. (Tyack et al. 2011, Moretti et al. 2014, Stanistreet et al. 2022). If animals habituate over time, the severity of behavioral responses based on BRS would be overestimated. Conversely, if animals sensitize over time, the severity would be underestimated.

1.1 Objectives of the 3S4 project

The objectives of the fourth phase of the 3S project (3S4) are to:

1. Investigate if exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals in killer whales, humpback whales and bottlenose whales; and

2. Investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

These objectives will be achieved by doing both long-duration CAS exposures to species for which the responses to short-duration PAS have already been investigated (Miller et al. 2012, 2014, 2015, Sivle et al. 2015, 2016, Wensveen et al. 2017, 2019). The first part of each exposure session will include a dose-escalation sequence designed to match previously conducted short-duration exposures. Using GPS location data of multiple tagged subjects received via ARGOS or directly from whale to ship, we aim to move the source vessel to achieve repeated dose escalations above the level at which 50% of subjects are expected to respond over 8 hrs, and compare responses to single dose escalation exposures over 40 min.

The study is a 4-year project starting January 2023, ending December 2026 with two 4-week field trials in the Norwegian sea of which the 3S-2023 trial is the first. We are also planning an optional 6-month expansion of the project with a third trial in 2025 to investigate the effect of CAS vs PAS in northern bottlenose whales (a species of beaked whale known to be very responsive to sonar). This extension of the project is not currently funded.

1.2 Navy needs

The project will address two critical navy needs: better understanding of the effect of sonar duty cycle (CAS vs PAS) and the effect of exposure duration.

Environmental impact assessment of new naval sonar technology (CAS) needs to be conducted based on knowledge gained from the impact of conventional sonar technology (PAS). In order to make this extrapolation, navies need to better understand whether or not the higher duty cycle of CAS leads to different types or severity of behavioral responses than PAS. This has so far only been studied in the field in sperm whales (Isojunno et al. 2020). Given the observed variation of responses to PAS across species, more information is needed on species potentially more sensitive to CAS. This is a critical deliverable from the 3S4 project.

Behavioral response studies of tagged free-ranging animals provide critical insight into behavioral responses of cetaceans to naval sonar. Studies on free-ranging animals are in a more realistic context than studies of captive animals. Furthermore, compared to observational studies of actual naval operations, these experiments are more controlled, and the measured data is easier to interpret (Harris et al. 2018). However, when BRSs are used, one must make assumptions to extrapolate to real naval scenarios. One assumption that is currently being tested by BRSs is the potential effect of the distance between the sonar source and the animal in driving or moderating behavioral responses (e.g., Wensveen et al. 2019). Another extrapolation that is important to assess is whether short duration BRS experiments can be used to predict severity of responses from more operationally relevant exposure durations. If animals habituate or sensitize during longer duration exposures this extrapolation is not trivial. We propose to address both of these questions in controlled experiments. By using cutting edge tagging technology (DTAG+, Mixed DTAG++ and satellite tags), and infrared mitigation technology (e.g., infrared thermal binoculars) we can expose several nearby animals at the same time to a realistic sonar dose over a realistic time duration, that includes nighttime exposures in the dark. This will allow us to collect and analyze data using state-of-the-art statistical approaches to better understand how BRS results can be extrapolated to assess the impact of real operational naval scenarios.

1.3 Tasks and priority of the 3S-2023 trial

1.3.1 Primary tasks

1. Tag killer whales with mixed-DTAG^{++} and expose them to dose escalating CAS or PAS twice over an extended period (8 hrs.).
2. Tag humpback whales with mixed-DTAG^{++} and expose them to dose escalating CAS or PAS twice over an extended period (8hrs).
3. Tag killer whales with splash tags in the core operation area (higher priority early in the trial)

1.3.2 Secondary tasks:

4. Tag killer whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible)
5. Tag humpback whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible)
6. Collect echosounder data to monitor the prey field.
7. Collect 24 h duration baseline data records of target species.
8. Collect drone footage of tagged subjects for body condition characterization.
9. Collect information about the environment in the study area (CTD, XBT)
10. Collect acoustic data using a towed array.
11. Collect sightings of marine mammals in the study area.
12. Perform sound source (SOC) long duration engineering test and harmonic characterization.
13. Collect herring samples around feeding whales.

1.3.3 Priorities

- Killer whales are higher priority than humpback whales.
- Primary focal whales are a higher priority than secondary focal whales.
- CAS exposures are higher priority than PAS exposures but optimize contrast.
- Mixed-DTAG^{++} deployments are higher priority than Splash tag deployments.
- Primary tasks are higher priority than Secondary tasks.

2 Method

Conducting controlled sonar exposure experiments on free ranging cetaceans at sea requires a variety of sophisticated equipment and expertise. The main platforms of the trial were the FFI RV HU Sverdrup II (HUS) with a regular crew of 7 persons. The research team consisted of 15 scientists on HUS with a multidisciplinary background, including experts in biology, underwater acoustics, oceanography, electronics, mechanical engineering, environmental science and operational sonar use.

Detailed descriptions of equipment used, and data collection procedures can be found in the 3S-2023 cruise plan (Appendix C). Below follows a short description of the basic experimental design of the experiments conducted and the data collected during the 3S-2023 trial.

2.1 Experimental design

The objectives of the project are to compare responses of killer whales and humpback whales exposed to continuous active sonar (CAS) to responses to pulsed active sonar (PAS), and to compare responses between short duration and longer duration exposures.

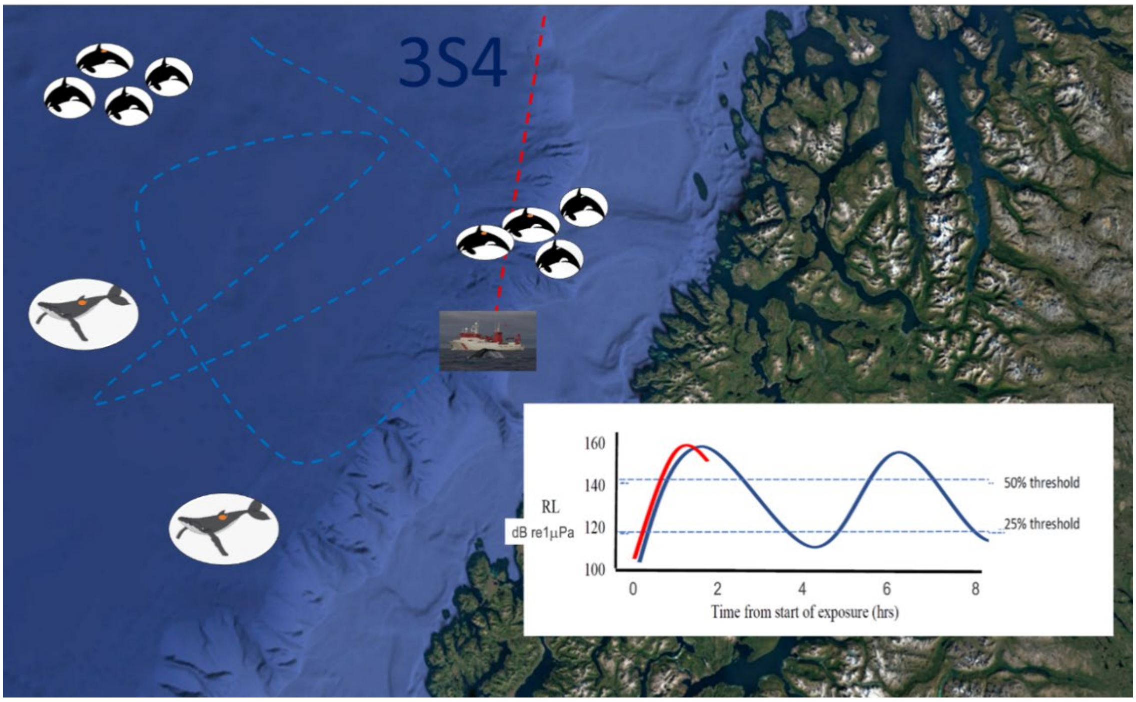


Figure 2.1 The objectives of the trial were achieved by doing long-duration CAS and PAS exposures using real-time GPS location data of multiple tagged subjects. The source was moved to achieve repeated dose escalations over 8 hrs. In the analysis, responses to the first approach will be compared to subsequent approaches.

The basic design of the sonar-controlled exposure experiments conducted during the 3S-2023 trial is that 1-2 target species focal subjects are tagged with the mixed-DTAG++. The tag records high resolution behavioral data and transfer the GPS-position of the tagged whales directly to the source vessel. In addition to the focal whales, additional non-focal whales can also be tagged and exposed in the same area. Non-focal whales are tagged with either mixed-DTAG++ or Wildlife Computers SPLASH10-F-333B Limpet tags. During the exposures we either use CAS signals or PAS signals during 8 hr long exposures. During this period focal animals are approached twice so that sonar received levels increases above their expected 50% response threshold.

Before the exposure, baseline behavior is recorded for 8hrs and after the exposure there is a post exposure period. The mixed-DTAG++ is set to release after about 24hrs.

During the analysis we will compare response onset and severity during CAS and compare to PAS. As we only conducted long-duration exposures, we will compare responses to the first approach to responses to the second approach in order to explore possible sensitization or habituation to sonar over time.

The LFAS source planned to be used for the sonar exposure experiments would have transmitted 1.3-2.0 kHz HFM at max source level (SL) of 214 dB re 1 μPa2·m2 during PAS and max SL of 201 dB during CAS, with single-pulse energy source level (ESL) of 214 dB re 1 μPa2·s·m2 during both CAS and PAS. However, due to technical issues with the SOCRATES source, we were forced to switch to MFAS signals using a source transmitting at higher frequencies and lower source level. The MFAS source transmitted 4-6 kHz HFM at max SL of 197 dB re 1 μPa2·m2 during PAS and max SL of 184 dB during CAS, with single-pulse ESL of 197 dB re 1 μPa2·s·m2 during both CAS and PAS.

2.2 Mixed-DTAG^{++}

The primary tag used for conducting CEEs during the 3S4-2023 trial is known as the 'mixed-DTAG++'. The mixed-DTAG++ is a suction-cup attached whale tag that can be attached using poles or the ARTS launching system (Kleivane et al. 2022). The initial version of the mixed-DTAG was first built in 2014 based upon the overall design of the DTAG version 2, including use of version DTAG2 suction cups. The mixed-DTAG was used successfully in the 3S3 research trials with sperm whales (Kvadsheim et al. 2020). Starting in 2021 and leading up to the 3S-2023 research trial, the mixed-DTAG was updated with two new sensors (hence the '++'): 1) a LOTEK F6G134A FastGPS-ARGOS logger, and 2) a Little Leonardo DVLW2000M130SW-4R video and data logger (Figure 2.2).

The mixed-DTAG++ has a suite of capabilities which are important for accomplishment of the 3S4 research project. The DTAG3 core unit records stereo audio, depth, 3-axis acceleration and 3-axis magnetism. The suite of DTAG3 sensors provide high-resolution data on the behaviour of each tagged whale, as well as recording sounds (call, echolocation clicks, tailslap sounds) produced by the tagged whale and nearby animals. The Little Leonardo sensor records 24hrs of movement data (as a backup in case of core unit failure), as well as wide-angle video which

reveals rich animal behaviour sequences and observations of each whale's environment, including prey observations. The audio recordings also enable direct measurement of the received level of sound recorded on the tag, including the experimentally transmitted sonar signals used in the study. The movement sensors, combined with GPS locations recorded by the LOTEK F6G134A logger enable detailed reconstruction of 3D dead-reckoned tracks of each tagged whale (Wensveen et al. 2015).

In addition to recording whale behaviour and characteristics of the received sonar signal for analysis upon recovery of the tag, the mixed-DTAG++ is designed to provide real-time, or near real-time information on the location of tagged whales without the requirement for visual tracking of the tagged whale. Three different types of on-animal whale positions are provided: 1) ARGOS-quality locations from the ARGOS satellite system, 2) GPS-quality locations sent via the ARGOS system, and 3) GPS-quality locations recorded on the research vessel using a CLS Goniometer antenna and receiver.

Figure 2.2 Left: Mixed-DTAG^{++} used in the 3S-2023 research trial. Note the suction cups used to attach the device to the skin of the whales. The DTAG3 core unit logs audio and movement of the tagged whale and operates the tag-release system via tygon tubes attached to each suction cup. The Little Leonardo video-data sensor records wide-angle video as well as 24-hours of depth and 3-axis accelerometer data. The LOTEK GPS-ARGOS unit records GPS signals, which are logged and then transmitted to the ARGOS satellite system. A LOTEK V7G 149A VHF transmitter is used to assist tagged whale tracking and for tag recovery. Sufficient flotation is included to enable good positive buoyancy of the device. Below: Four mixed-DTAG^{++} units ready for deployment during the 3S-2023 research trial.

Substantial field-testing of the mixed-DTAG++ was undertaken during pilot studies in coastal Iceland (hosted by Drs Samarra and Wensveen), in summers 2021-2023. Performance of all of the Mixed-DTAG++ systems were found to be acceptable during the summer 2023 trial, and clear recommendations were given for tag deployment (Appendix F). A key recommendation

was that Mixed-DTAGs be placed flat on the body ideally located between the blowhole and the dorsal fin (Figure 2.3). To consistently achieve this placement, tag poles were prepared with the tag suction cups oriented 90° to the pole axis (Figure 2.3). This orientation enables tags to be lowered directly onto the desired location on the body. The mixed-DTAG++ is also designed to be deployed using the ARTS launching system. Because of greatly reduced control in tag placement using ARTS, it was recommended that the ARTS tagging system only be used when pole tagging is deemed not to be feasible.

Figure 2.3 Left: Mixed-DTAG^{++} deployment Oo23_181b illustrating the optimal placement of the tag for effective performance of the GPS-ARGOS system. Flat placement on the body between the dorsal fin and blowhole. (Photo A. Selbmann). Right: Illustration of the tag-pole setup for attached mixed-DTAG^{++} tags by lowering it onto the body between the dorsal fin and the blow hole. (Photo G. Sato).

2.3 Data collection

The controlled exposure experiments were the primary task of the 3S-2023 trial. The primary data collected was thus the behavioral data collected by the mixed-DTAG^{++} and SPLASH10-F-333B Splash Limpet tags. The mixed-DTAG^{++} records high resolution movement and dive data, GPS positions at the surface and the camera records other animal and prey around the focal whales. In addition, the acoustic sensor of the tag records vocal behavior of the focal animal (and other animals nearby) and the received level of sonar we expose them to. The Splash tag transfer lower resolution dive data and GPS positions of the whales via Argos or Goniometer antenna.

In addition to data on animal behavioral recorded by the tag, we also collected data on the prey field around the focal whales and in the general area. This was done using echosounder on the source vessel and by collecting fish samples. AIS data of fishing vessels were also collected to analyze potential interactions of the whales with the fishing fleet. Finally, data on the acoustic environment (sound speed profiles) were collected using XBTs and a CTD to understand how the sonar signals propagated in the area.

2.4 Risk management and permits

Experimental exposure of marine mammals to high levels of sound implies some risk that animals could be negatively affected (that is why it is important to study it). The experiments reported here were conducted under permit from the Norwegian Animal Research Authority (permit no 23/110085), and experimental procedures were approved by the Animal Welfare Ethics Committee at the University of St Andrews. A separate risk assessment and management plan was developed for the trial to minimize risk to the environment, risk to third parties and risks to humans involved in the operation (Appendix D). This document also specifies suitable mitigation measures, endpoints and responsibilities.

Permits and ethics approvals implies monitoring of a 500m mitigation action zone by marine mammal observers on the source vessel during sonar transmissions. If any mammals appear within 100 m from the source, the source was immediately shut down. During transmission in the dark the observers was equipped with Pulsar Merger thermal binoculars. The performance of the thermal binoculars was tested in the field before the trial (Kleivane 2023) (Appendix E).

3 Results

3.1 Overview of activities and achievements

During the 3S-2023 trial 13 mixed-DTAG++ and 6 limpet SPLASH10-F-333B tags were deployed to killer whales and 5 mixed-DTAG++ were deployed to humpback whales (Table 3.3). Of the 18 mixed-DTAG++ deployments, 11 were baseline-only records with durations varying from 5 min to 28.3 hrs and 2 were deployments on nonfocal animals containing baseline and exposure data. Four long-duration controlled exposure experiments (two CAS and two PAS) on multiple focal animals (4 killer whales and 1 humpback whale) were conducted using direct animal to ship GPS tracking.

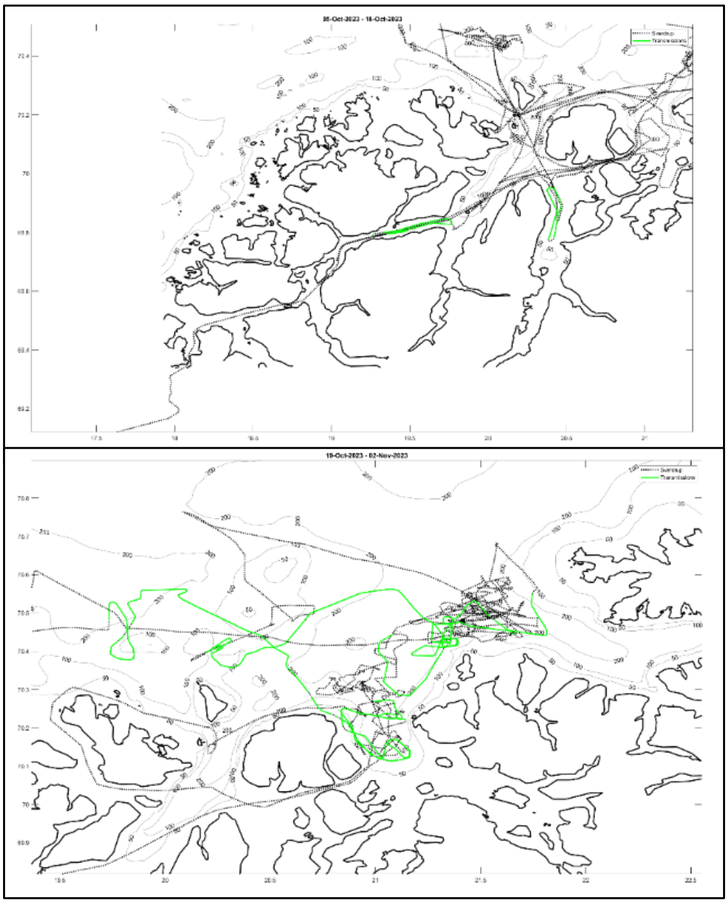


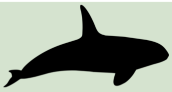
Figure 3.1 Overview of the sailed tracks of RV HU Sverdrup II during the first two weeks (upper panel) and second two weeks (lower panel) of the 3S-2023 trial. When the track is green the Socrates sonar source was transmitting. During the first period, sonar transmissions where mostly engineering tests, while in the second period, we conducted all 4 CEEs.

The first days of the trial were dominated by installation, testing and training activity (Figure 3.1 og Table 3.1). Overview of weather at noon and overall activity during the 3S-2023 trial. Wind force is given on the Beaufort scale. The operational status was either fully operational (green), partly operational/reduced effort (yellow) or not operational (red). KW refers to killer whales and HW refers to humpback whales. Further details of daily activities are given in Appendix B. Initial testing of the Socrates II source revealed a very serious problem with the low frequency (LFAS) transducer. Socrates III was shipped by the Netherlands navy from Spain to Tromsø, but upon arrival it was found to have serious problem too and could not be used.

Table 3.1 Overview of weather at noon and overall activity during the 3S-2023 trial. Wind force is given on the Beaufort scale. The operational status was either fully operational (green), partly operational/reduced effort (yellow) or not operational (red). KW refers to killer whales and HW refers to humpback whales. Further details of daily activities are given in Appendix B.

Date	Area	Weather	Wind	Sea State	Activity	Ops. Status by watches
Oct 4	Harstad	Rendezvous, joint briefing				
Oct 5	In port Harstad	Rain	W3	0	Embarkment, Mobilization	
Oct 6	In port Harstad	Clouded	SW3	0	Testing, training, safety briefing	
Oct 7	Vågsfjorden	Clouded	N1	1	Safety training with tag boats, harmonics and endurance test of Socrates. Overnight transit	
Oct 8	Lenangen - Ulsfjorden	Clouded	NW5	2	Working to fix Socrates. Tagging and MMO training. VHF and Goniometer range and bearing tests of tags.	
Oct 9	Fugløybanken	Clouded	E5	2-3	Tagging KW and HW. Tagged a big male kw with a splash tag	
Oct 10	Fugløybanken	Clouded	SW2	2	Tagging KW and HW. Tagged a big male kw with a splash tag	
Oct 11	Lyngen-Kvænangen	Rain/snow	N8	3	Testing the MFAS source of the SOCRATES II with 4-6kHz CAS and PAS. Visual and acoustic survey - no whales	
Oct 12	Grøtsundet	Clear sky	S4	1	Dropped of MOBHUS for repair in Tromsø. Testing MFAS source.	
Oct 13	Lopphavet	Clouded	NW4	3	Working with KW and HW. Deployed another splash tag to a male KW	
Oct 14	Lopphavet	Clear sky	W2	2	Working to tag with mixed-DTAG^{++}. Many whales, but no success.	
Oct 15	Kvænangen	Rain	NE5	3	Searching for whales in-shore.	
Oct 16	Kvænangen	Partly clouded	NE5	1	Searching for whales ins-shore. Weather too rough off-shore.	
Oct 17	Lopphavet - Fugløybanken	Clear sky	SW2	2	Deployed three splash tags to KW. Tagged two KWs with mixed-DTAG^{++} around fishing vessels, but both came off before any exposure was conducted.	
Oct 18	Tromsø	Snow	N4	1	Transit to Tromsø, crew change and replacement of Socrates II with Socrates III.	
Oct 19	Tromsø - Kvænangen	Clouded	NE2	1	Transit back to Kvænangen, tagging killer whales around fishing fleet	
Oct 20	Kvænangen	Snow	N7	4	Two mixed-DTAG^{++} deployed (KW, HW). CEE I MFAS CAS	
Oct 21	Kvænangen	Snow	N7	4	Searching for and tagging whales in in-shore waters during daylight and around fishing boats at night.	
Oct 22	Lopphavet	Clouded	N5	4	Tagging around fishing fleet, tagged a big male and a female KW	
Oct 23	Kvænangen	Partly clouded	NW2	3	CEE II MFAS PAS, transit to new area	
Oct 24	Sørøysundet - Lopphavet	Clear sky	SE2	2	Tagging KW free swimming and around fishing vessels. 2 tags deployed (2KW) MFAS CAS CEE III	
Oct 25	Sørøysundet - Lopphavet	Clear sky	NW3	3	CEE III MFAS CAS, transit to new area starting tagging again	
Oct 26	Lopphavet	Snow	N3	2	Tagged a HW for baseline, 2KWs for CEE	
Oct 27	Lopphavet				CEE IV MFAS PAS, tag turn-around	
Oct 28	Sørøysundet - Lopphavet	Clouded	S4	2	Tagging around fishing vessels, two tags deployed (KW, HW) for baseline records	
Oct 29	Sørøysundet - Lopphavet	Clear sky	NE2	1	Tagging around fishing vessels, two tags deployed (HW, KW)for baseline record	
Oct 30	Sørøysundet - Lopphavet	Snow	W4	2	Tagging, 1 tag deployed for baseline (KW), MFAS harmonics test, transit to Harstad	
Oct 31	Harstad				Transit to Harstad, hot wash, packing	
Nov 1	Harstad				Demobilization in Harstad, celebration	
Nov 2	Harstad				Offloading, dissembarkment	

Table 3.2 *Hours of mixed-DTAG++ data collected during the 3S-2023 trial.*

	Baseline only	Experimental	**Total**
	34.4	128.1	162.5
	63.35	19.6	82.95
Total	**97.75**	**147.7**	**245.45**

We therefore decided to conduct the experiments with the MFAS source, which transmits sonar signals at higher frequencies and lower maximum source level.

Figure 3.2 Collection of pictures demonstrating the main activities during the 3S-2023 trial. Upper left; Sighting killer whales from RV HU Sverdrup II (photo G. Sato). Upper right; working to tag whales in the dark, occasionally enlightened by the northern light (photo J. Bort). Lower left; tagging whales around purse seine fishing vessels (Photo M. Müller). Lower right; testing the Socrates source and doing controlled exposure experiments (photo F.P. Lam).

Furthermore, in the first two weeks, we could not tag whales around the herring purse seine fishing vessels as intended because the fleet arrived late due to an apparent delay in the mackerel fishery further south involving the same vessels. When the fishing fleet arrived, it worked very far offshore where the weather was too rough for us to work. Even though we found both whales and herring closer to the coast, tagging was challenging in these first two weeks of the trial, and we were only able to deploy the limpet tags, not the mixed-DTAG++.

After the mid-sail crew change, our luck changed, and our problems were mostly resolved. The weather improved, the fishing fleet moved closer to the coast and the sonar source issue was solved. We therefore tagged many whales around the fishing vessel in the second period and successfully conducted 4 CEEs (Table 3.3).

Table 3.3 *Overview of tag deployments and controlled exposure experiments (CEEs). Experiments used Pulsed Active Sonar (PAS; 1s pulses) or Continuous Active Sonar (CAS; 19s pulses) signals. CEE were conducted using mixed-DTAG^{++} and the SOCRATES source on RV HU Sverdrup II with 20s pulse repetition time. SPLASH10-F-333B tags were deployed to record overall movements of killer whales in the area and their baseline diel cycle. F1 is the primary focal animal, F2 is the secondary focal, F0 are non-focal animals.*

Tag type	Deployment ID	Species	Date/Area	Experiment / data collected
Splash Tag	SAT23_1	Killer whale	October 9th Fugløybanken	Baseline diel cycle and overall movement of whales in the area
Splash Tag	SAT23_3	Killer whale	October 10th Fugløybanken	Baseline diel cycle and overall movement of whales in the area
Splash Tag	SAT23_5	Killer whale	October 13th Lopphavet	Baseline diel cycle and overall movement of whales in the area
Splash Tag	SAT23_2	Killer whale	October 17th Lopphavet	Baseline diel cycle and overall movement of whales in the area
Mixed-DTAG^{++} Mixed-DTAG^{++}	Oo23_290a* Oo23_290b*	Killer whale Killer whale	October 17th Fugløybanken	Baseline data. Tags released prematurely, no CEE.
Splash Tag	SAT23_4	Killer whale	October 18th Fugløybanken	Baseline diel cycle and overall movement of whales in the area
Splash Tag	SAT23_6	Killer whale	October 18th Fugløybanken	Baseline diel cycle and overall movement of whales in the area
Mixed-DTAG^{++} Mixed-DTAG^{++}	Oo23_292a* Oo23_292b – F1 Mn23_293a – F2	Killer whale Humpback whale	October 19-20th Kvænangen	Baseline CEE I MFAS CAS

Mixed-DTAG^{++}				
Mixed-DTAG^{++} Mixed-DTAG^{++}	Oo23_295a – F2 Oo23_295b – F1	Killer whale Killer whale	October 22-23rd Lopphavet	Baseline CEE II MFAS PAS
Mixed-DTAG^{++} Mixed-DTAG^{++}	Oo23_297a* - F2 Oo23_297b – F1	Killer whale Killer whale	October 24-25th Lopphavet	Baseline CEE III MFAS CAS
Mixed-DTAG^{++} Mixed-DTAG^{++} Mixed-DTAG^{++}	Mn23_299a* - F2 Oo23_299a - F1 Oo23_299b** - F0	Humpback whale Killer whale Killer whale	October 26-27th Lopphavet	Baseline CEE IV MFAS PAS
Mixed-DTAG^{++} Mixed-DTAG^{++} Mixed-DTAG^{++}	Mn23_300a* OO23_301a* Mn23_301a*	Humback whale Killer whale Humback whale	October 27-28th Lopphavet	Baseline
Mixed-DTAG^{++} Mixed-DTAG^{++}	Mn23_302a Oo23_302a**	Humback whale Killer whale	October 29 Lopphavet	Baseline
Mixed-DTAG^{++}	Oo23_303a*	Killer whale	October 30th	Baseline

** Tag off before CEE, **No remote tracking*

3.2 Sonar exposure experiments

Table 3.4 Overview of controlled sonar exposure experiments (CEEs) conducted during 3S-2023. PAS is Pulsed Active Sonar runs (1s pulses every 20s), CAS is Continuous Active Sonar runs (19s pulses every 20s). MFAS means 4-6 kHz HFM signals transmitted at max source level (SL) of 197 dB re 1 $\mu Pa^2 \cdot m^2$ during PAS and max SL of 184 dB during CAS, with energy source level (ESL) of 197 dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ during both CAS and PAS. KW is killer whales and HW is humpback whales. Closest point of approach (CPA) was estimated during each approach.

CEE #	Focal #	Species	Deployment id	Tag id	Approach #	CPA (UTC)	CPA est
CEE I MFAS CAS	1	KW	Oo23_292b	Scooby	1	20Oct1052	500m
	2	HW	Mn23_293a	Homer	1	20Oct1124	600m
	1	KW	Oo23_292b	Scooby	2	20Oct1450	750m
	2	HW	Mn23_293a	Homer	2	20Oct1453	No est
CEE II MFAS PAS	1	KW	Oo23_295b	Elmo	1	23Oct0611	500m
	2	KW	Oo23_295a	Scooby	2	Tracking error	--
	1	KW	Oo23_295b	Elmo	1	23Oct1040	No est
	2	KW	Oo23_295a	Scooby	2	Tag off	--
CEE III MFAS CAS	1	KW	Oo23_297b	Homer	1	25Oct0853	400m
	1	KW	Oo23_297b	Homer	2	25Oct1250	2000m
	2	KW	Oo23_297a	Scooby	--	Tag off	--
CEE IV MFAS PAS	1	KW	Oo23_299a	Marge	1	27Oct0913	750m
	1	KW	Oo23_299a	Marge	2	27Oct1523	550m
	2	HW	Mn23_299a	Elmo	--	Tag off	--
	0	KW	Oo23_299b	Simba	--	No-tracking. Tag off during 1st approach	--

The following figures (3.5-3.14) shows an extract of the data from the four CEEs.

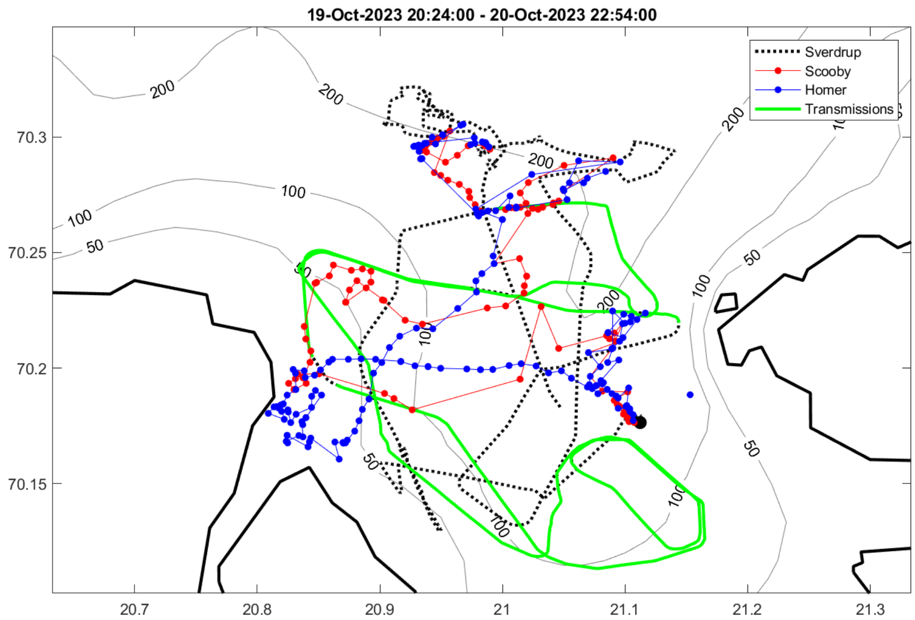


Figure 3.3 CEE I – MFAS CAS: Geographical tracks from the CEE-tool of source vessel without transmissions (⋯⋯) and when transmitting sonar signals (—), focal 1 whale Oo23_292b (—) and focal 2 whale Mn23_293a (—).

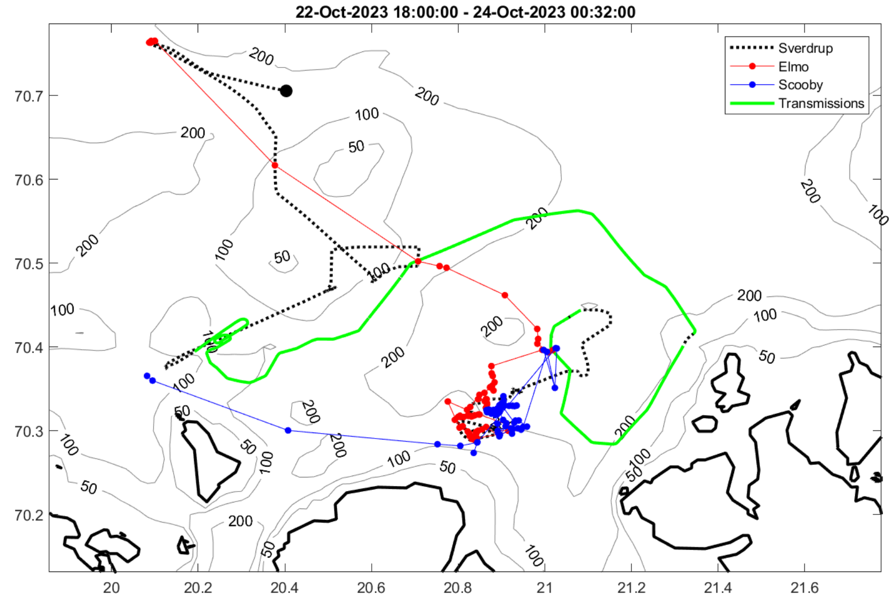


Figure 3.4 CEE II – MFAS PAS: Geographical tracks from the CEE-tool of source vessel without transmissions (⋯⋯) and when transmitting sonar signals (—), focal 1 whale Oo23_295b (—) and non-focal whale Oo23_295a (—).

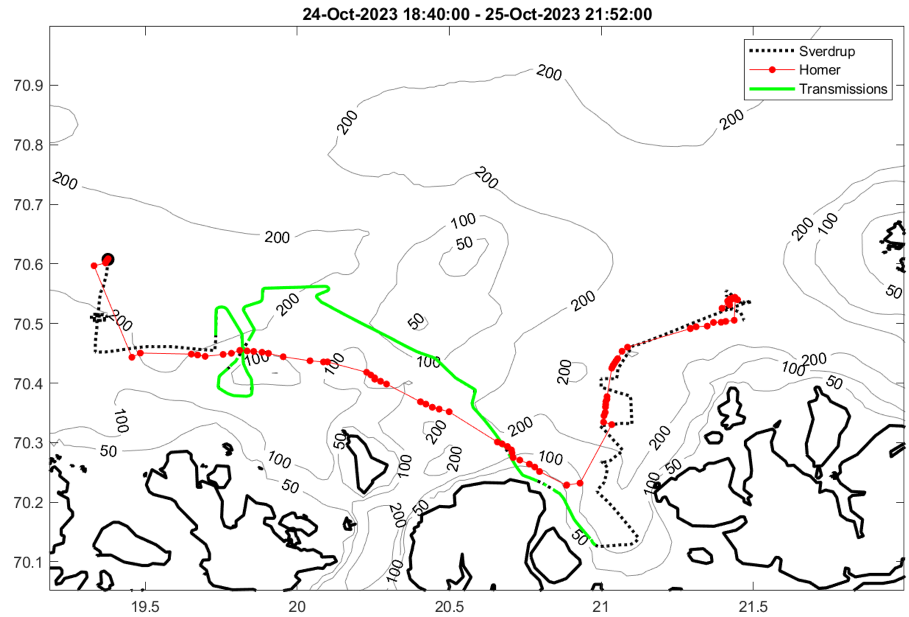


Figure 3.5 CEE III – MFAS CAS: Geographical tracks from the CEE-tool of source vessel without transmissions (⋯⋯) and when transmitting sonar signals (—) and focal 1 whale Oo23_297b (—).

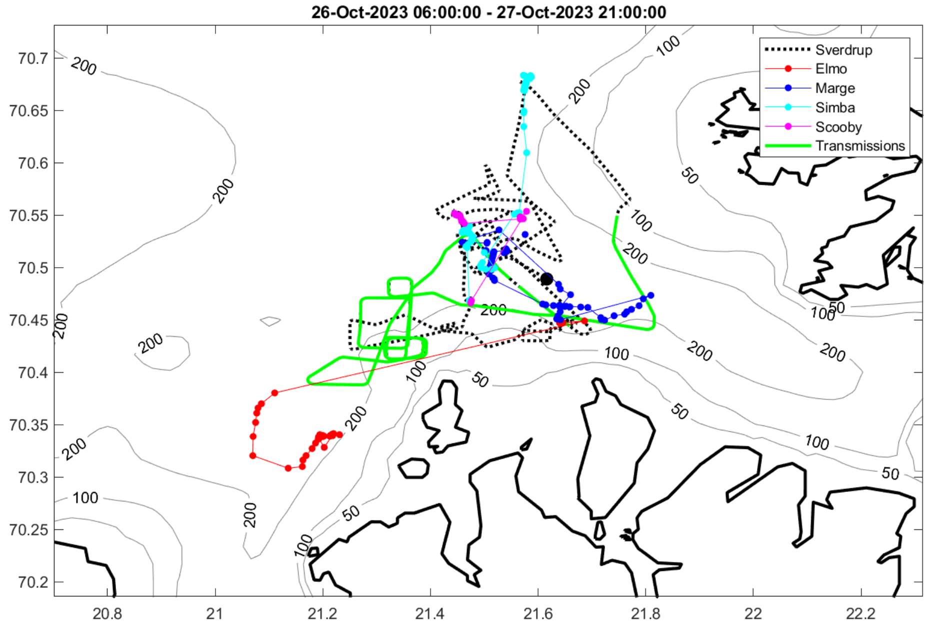


Figure 3.6 CEE IV – MFAS PAS: Geographical tracks from the CEE-tool of source vessel without transmissions (······) and when transmitting sonar signals (—), focal 1 whale Oo23_299a (—), focal 2 whale Mn23_299a (—) and non-focal whale Mn23_299b (—).

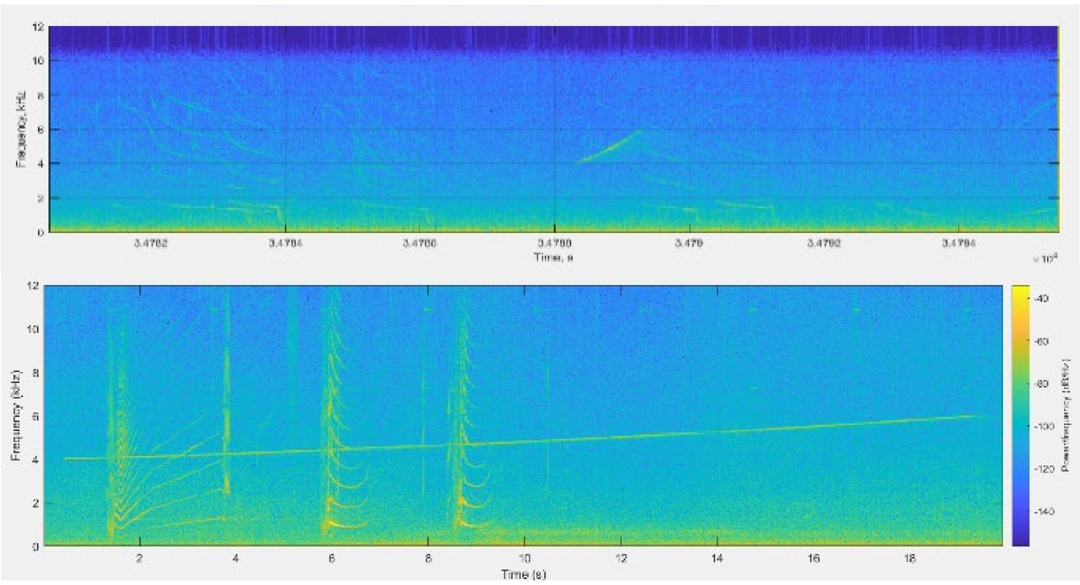


Figure 3.7 Top: Spectogram of DTAG recording Mn23_293a during CEE I showing killer whale vocalizations and a PAS pulse during ramp-up. Bottom: Spectogram of DTAG recording Oo23_292b during CEE I showing loud killer whale vocalizations and a CAS pulse.

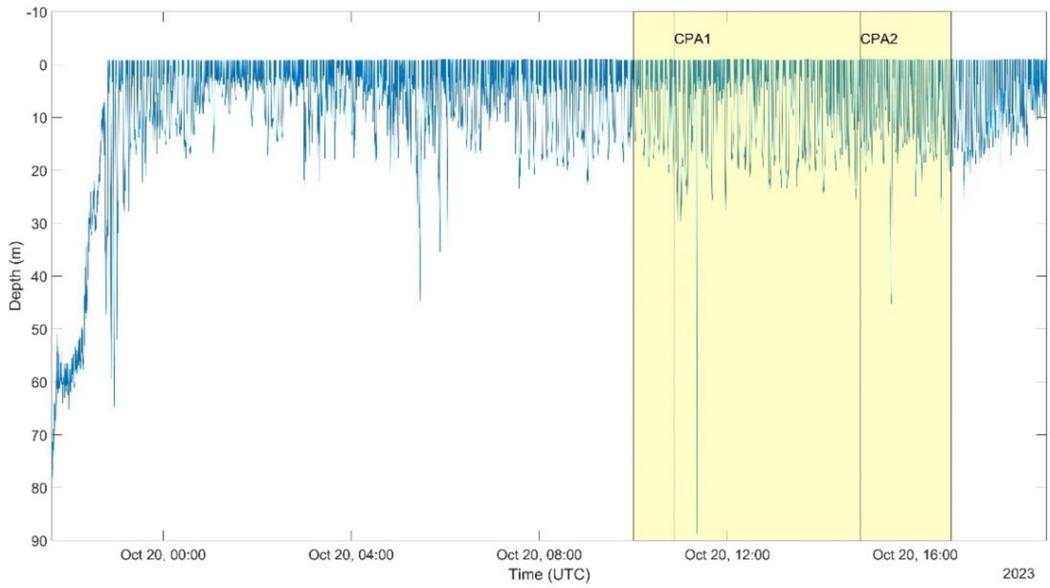


Figure 3.8 Time-depth plot of focal 1 whale Oo23_292b during CEE I. Note that depth data at the start of the deployment were corrupted.

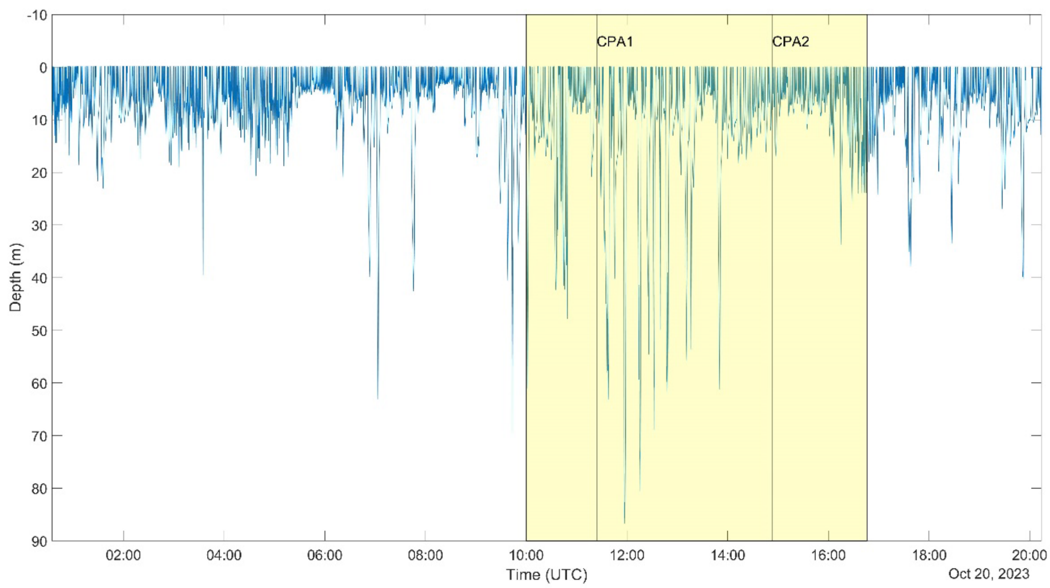


Figure 3.9 Time-depth plot of focal 2 whale Mn23_293a during CEE I.

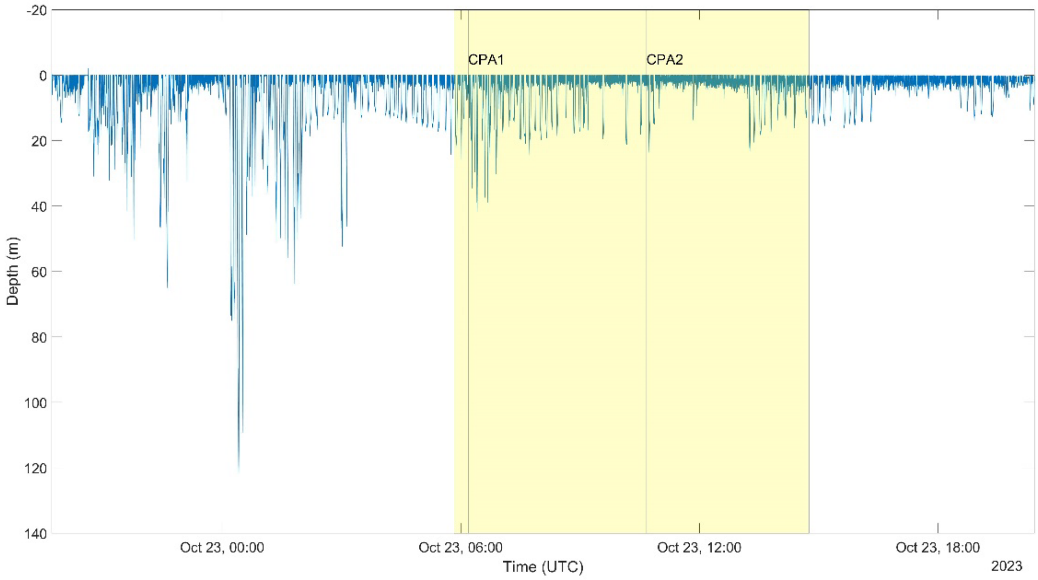


Figure 3.10 Time-depth plot of focal 1 whale Oo23_295b during CEE II.

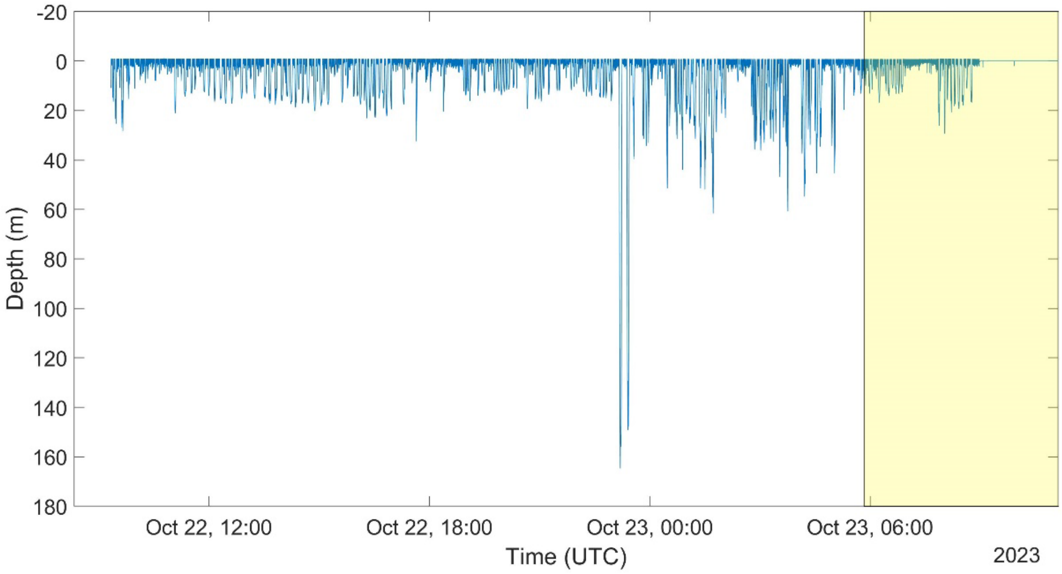


Figure 3.11 Time-depth plots of focal 2 whale Oo23_295a during CEE II.

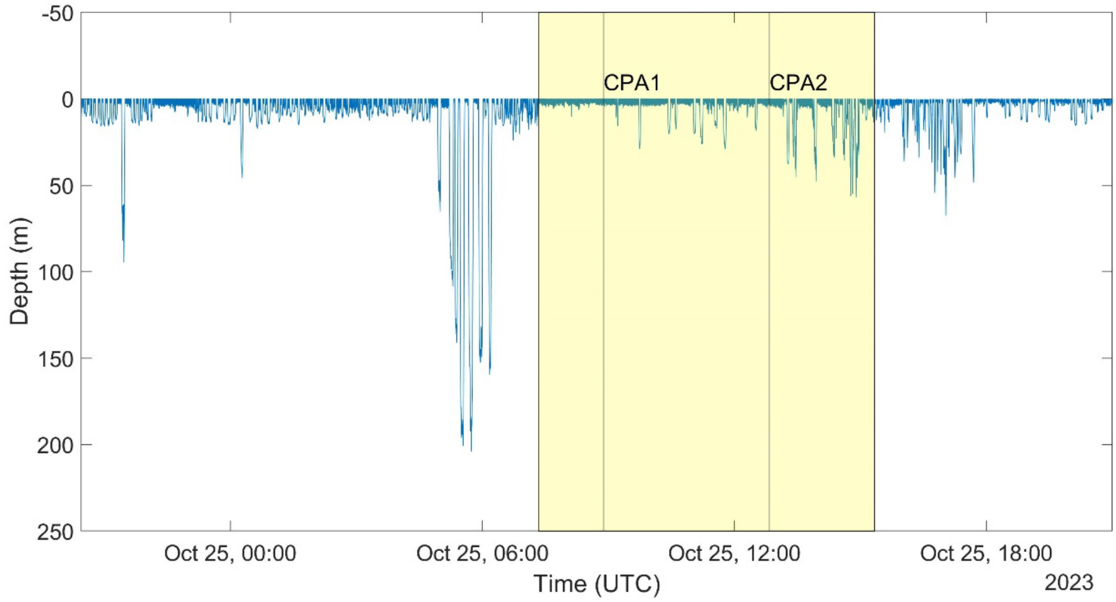


Figure 3.12 Time-depth plots of focal 1 whale Oo23_297b during CEE III.

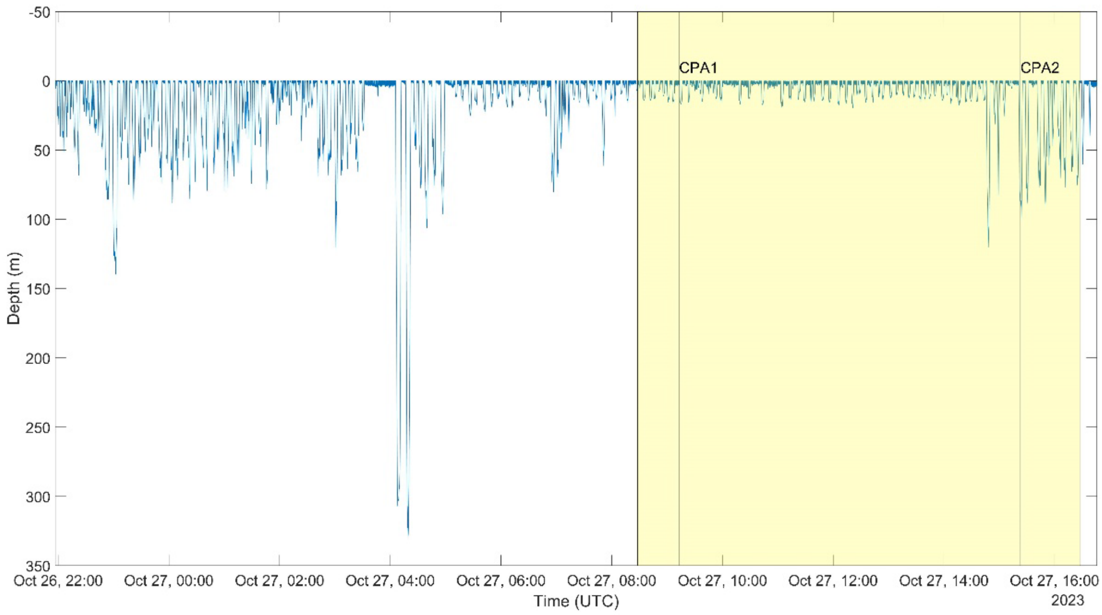


Figure 3.13 Time-depth plot of focal 1 whale Oo23_299a during CEE IV.

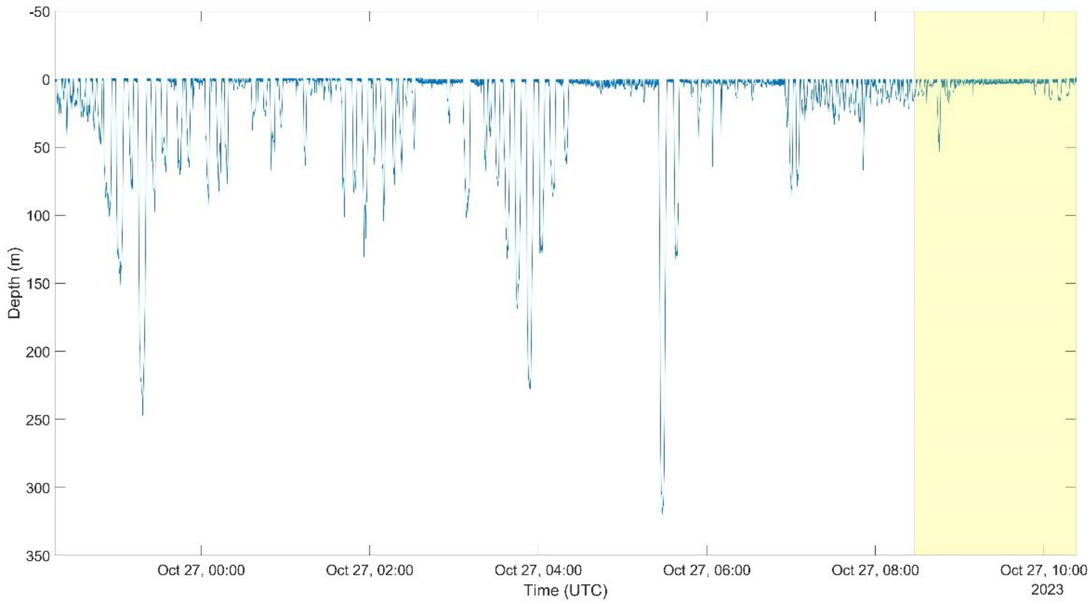


Figure 3.14 Time-depth plot of focal 2 whale Oo23_299b during CEE IV.

3.3 CEE tool

The CEE tool is a new developed software package designed to support the Controlled Exposure Experiments. The version that was used during the trial featured the following:

- Bathymetry (depth-contours) and coastlines.
- Own ship track
- AIS tracks of other vessels in the area
- Interactive Range-Bearing tool on the map
- Manual input of positions (markers)
- Tracks of tagged whales composed of the following sources:
    - Position information retrieved from the ARGOS satellite network (ARGOS quality positions with error ellipse).
    - Bearing and Position (GPS-quality) information via two CLS Goniometer antennae and receivers.
    - Position information via manual user input (for example Visual detections)

The tool consists of two screens; one screen shows a geographic overview of the above-mentioned features and includes the user interface tools to edit some of these data. The second screen provides an overview of the historic and predicted range to the tagged whales and can be used to tune the course of H.U. Sverdrup II to comply with the planned experimental design.

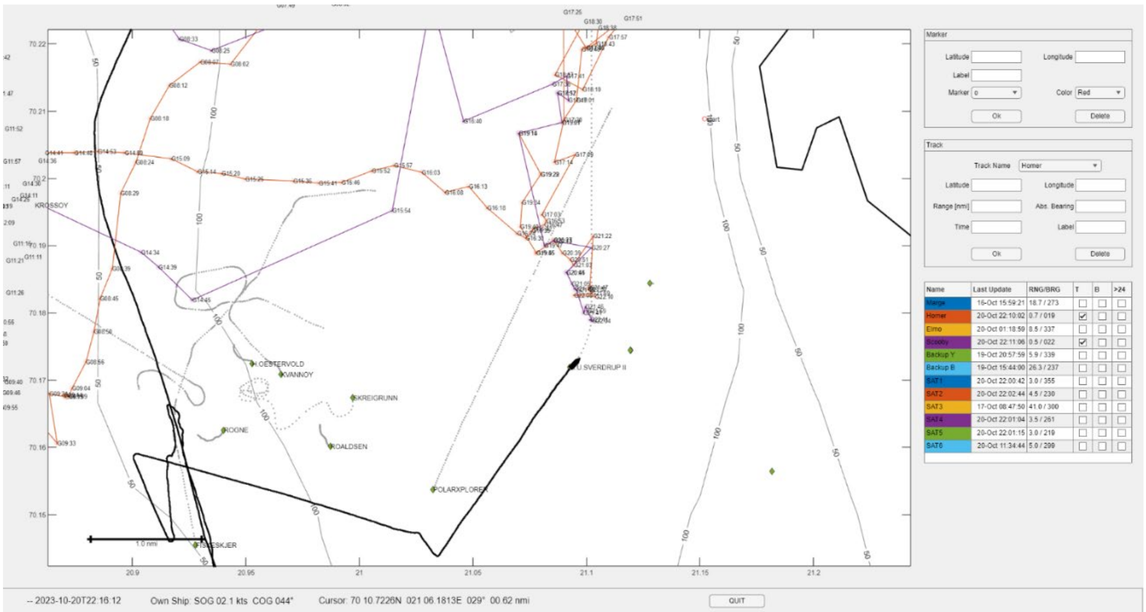


Figure 3.15 Example of CEE tool showing the situation at the end of an exposure. Two tagged whale tracks are shown in orange and in purple. Track of H.U. Sverdrup II is shown in black, and tracks of other ships are shown using AIS data in gray.

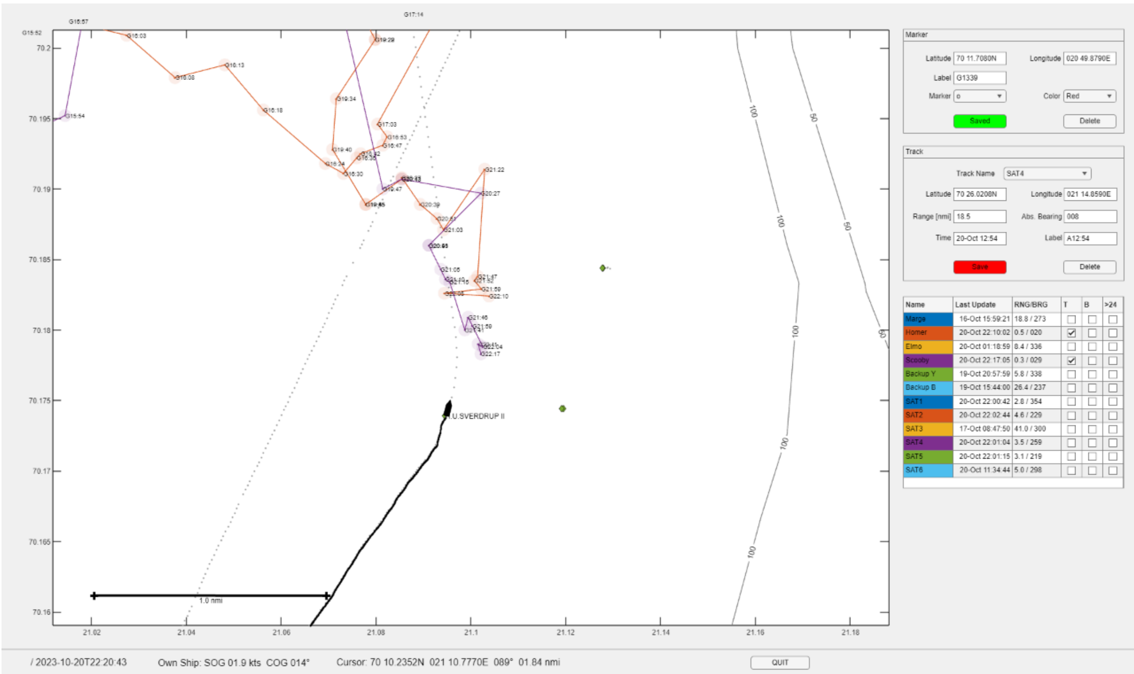


Figure 3.16 More detailed view of tag locations, each tag position update is marked by an error circle and the associated time.

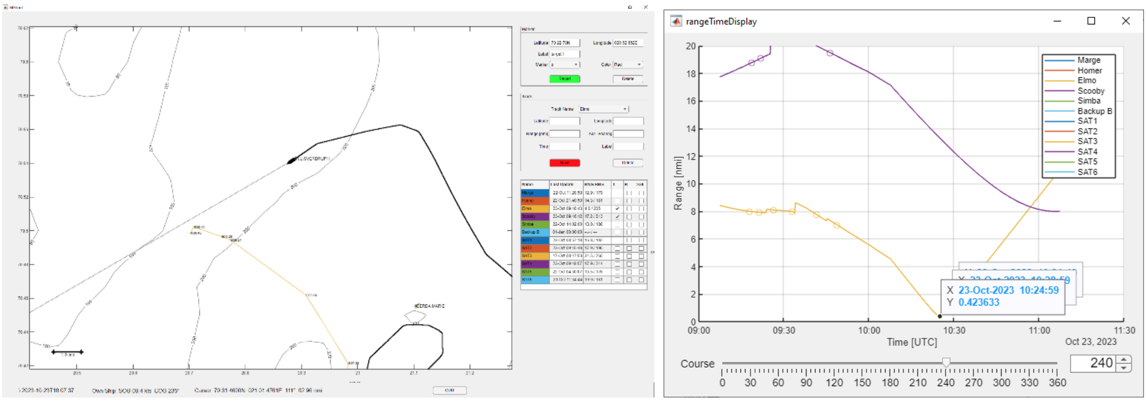


Figure 3.17 Screenshot of CEE-tool during 2nd approach to focal 1 during CEE 2. Left panel shows map with track of source vessel and focal whale. Right panel shows the Range-Time display. It depicts the range to a focal whale track for the last hour and a predicted range for the next hour based on the last known whale position, and the source vessel sailing with speed of 8 kts and a user defined course (240°). In this case the estimated CPA to the focal whale is 0.4nmi.

Overall, the CEE tool was very useful and helped significantly with the tracking of the whales, larger-scale planning, and the execution of the experimental vessel approaches. ARGOS cross-bearing data retrieved from the satellite network were rarely used for whales tagged with mixed-DTAGs, because we received many GPS-quality locations in near-real time via the Goniometer antennas. On the other hand, ARGOS data from the Splash tags were also visualised and these provided additional context about whale presence in the larger area. The line-of-sight reception of the tag locations using the Goniometer worked above expectations. The position updates were received reliably at regular intervals and ranges were well suited for the experimental design (Figure 3.18).

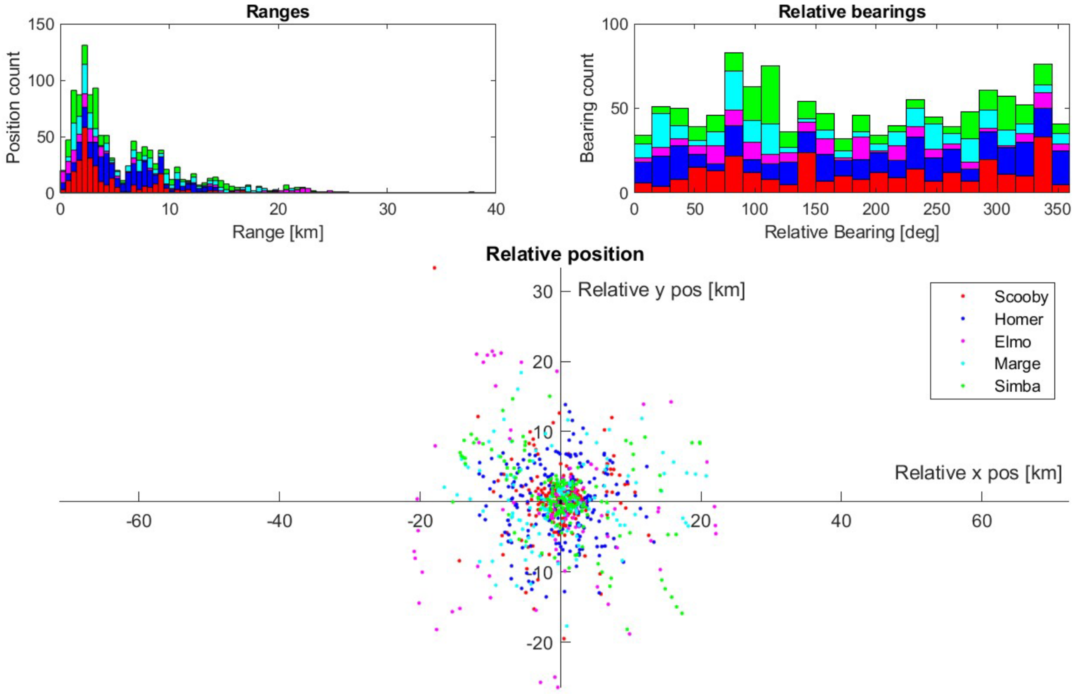


Figure 3.18 Range and bearing histograms of all combined mixed-DTAG^{++} deployments (top panel), and relative positions as function of tag ID (bottom panel).

During the trial several suggestions for improvement were identified:

- The CEE tool becomes very sluggish and unresponsive after a few days of operation. This has to do with the number of plots and ellipses drawn on the map, which Matlab does very slowly. We should investigate better ways of plotting, and managing the data plotted.
- Improve responsiveness when dragging or zooming on the map, which is related to the previous issue.
- Have better methods to clean up the track database; after several days the map could become very cluttered with "old" tracks.
- Use more, or less accurate, bathymetry data. The current resolution is not useful for navigation planning and should be improved or removed.
- Better status indication of data streams, especially for the real-time data received by the Goniometer. During the experiments, we found that these data may drop out or is duplicated due to errors in the gonio data stream. The CEE tool does not notice these dropouts. Better status monitoring could help diagnose problems faster.

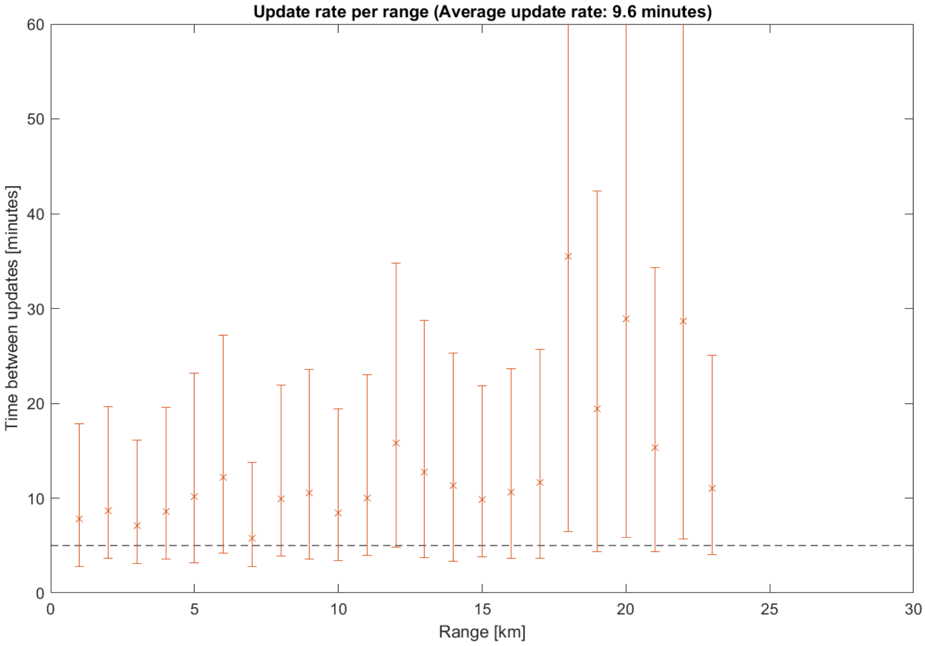


Figure 3.19 Measured update rates of all combined tag deployments versus range. The Lotek Fastlock GPS-ARGOS unit inside the tag updates its GPS fix every five minutes. This position is transmitted every two minutes. For ranges up to the line-of-sight range (≈ 17 km) the average update rate is between 5 and 10 minutes, for longer ranges this slowly increased.

3.4 Visual effort and data collection

There was a total of 407 sightings of seven cetacean species made throughout the trial, and 87 re-sightings of previously sighted animals or groups. The most observed species was killer whales (*Orcinus orca*) (200), followed by humpback whales (*Megaptera novaeangliae)* (126), fin whales (*Balaenoptera physalus*) (36), minke whales (*Balaenoptera acutorostrata*) (4), sei whale (*Balaenoptera borealis*) (1), sperm whales (*Physeter macrocephalus)* (1) and harbor porpoise (*Phocoena phocoena)* (1). There were 21 sightings of unidentified balaenopterids, and 17 unidentified whale sightings (Figure 3.20).

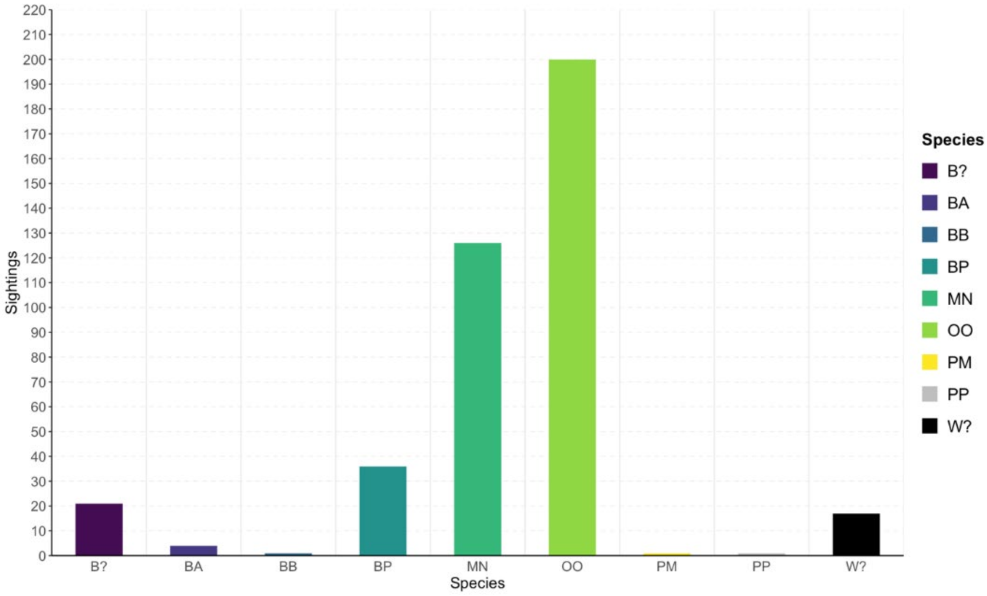


Figure 3.20 Total number of sightings per species sighted over the entire 3S-2023 trial period. BA=Balaenoptera acutorostrata (Minke whale); BB=Balaenoptera borealis (Sei whale); BP=Balaenoptera physalus (Fin whale); MN=Megaptera novaeangliae (Humpback whale); OO=Orcinus orca (Killer whale); PM=Physeter macrocephalus (Sperm whale); PP=Phocoena phocoena (Harbour porpoise); B?=unidentified balenopterid; W?=unidentified whale.

The visual effort of the 3S-2023 sea trial was different compared to other 3S trials. This was because of the different tagging procedures and exposure protocol. Visual effort on the first two weeks of the sea trial were also significantly different compared to the two last weeks of the trial. In the first two weeks marine mammal observers (MMOs) rotated on the observation deck (obs deck) of HU Sverdrup II (HUS) during day light. MMOs searched for whales and provided visual support to the tag teams in the tagging phase. The height of the observation deck provides additional value to the tag teams. Visual tracking of animals from the observation deck provided the opportunity to keep track of the different whales in the searching area and to guide the tag teams in the tag boats. Tracking animals from the tag boats is challenging because the tagboat is very close to the water surface compared to the observation deck.

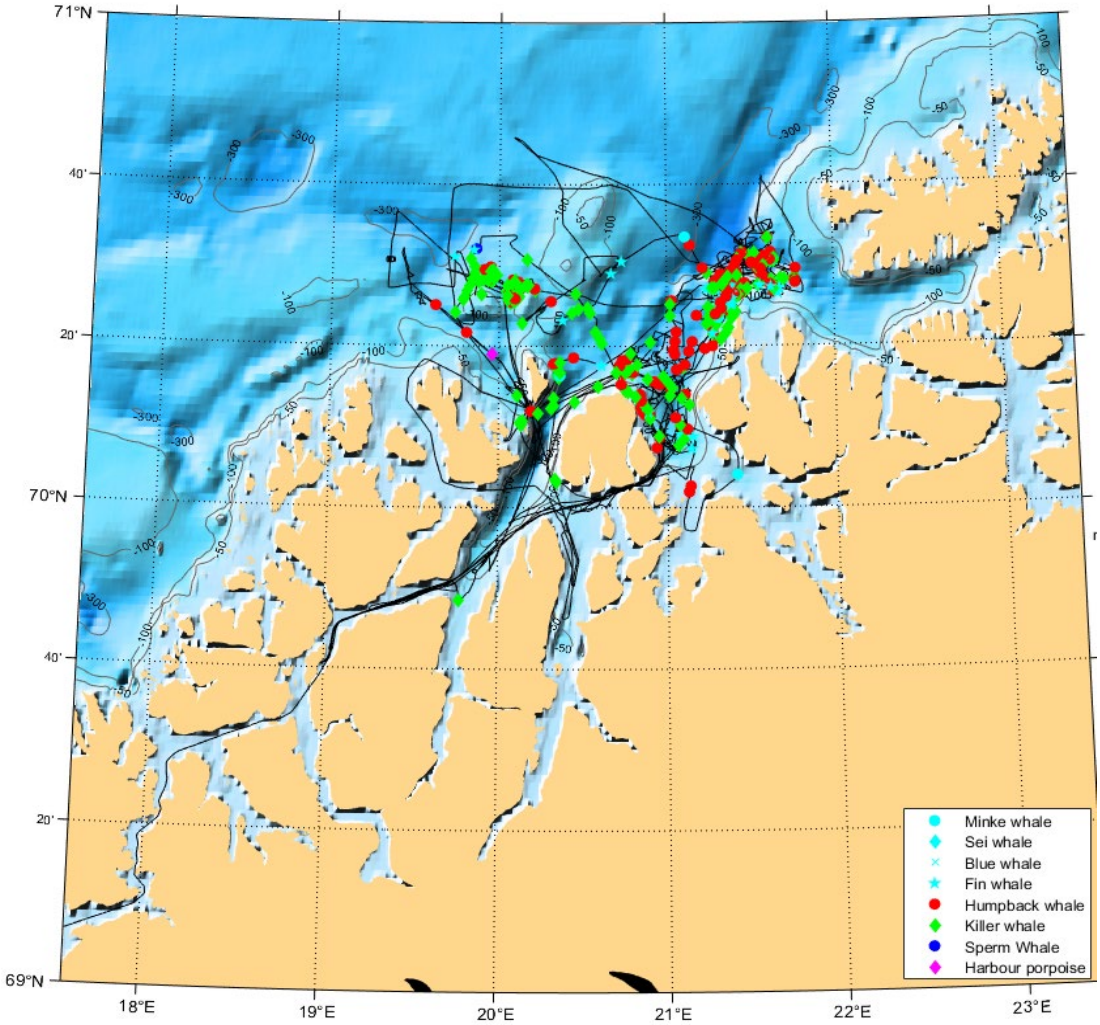


Figure 3.21 GIS plots of marine mammals sightings made by the MMOs on HU Sverdrup during 3S-2023. Locations are based on the vessel track and sighting times recorded in Logger

A 360-degrees angle board was used to measure the angle to the whale sighting location relative to the heading of the vessel. The ship-whale range estimates were based on the reticle count of the big eyes and hand-held binocular, respectively. When reticles could not be counted to the sighting, e.g., due to poor weather conditions (sea state, swell, showers) or when land was visible on the horizon, the ranges were estimated by eye. These field estimates were reported as estimates by eye, although these were often guided by binocular observations.

Throughout the two first field work weeks (7th October – 18th October) the window of day light decreased starting from 6.00 AM to 18.45 PM local time in the beginning to 7.15 AM to 18.00 PM. The weather also influenced visibility during morning and evening twilight zone. With clear sky the visibility increased. MMOs made sure to be on the observation deck before twilight started in the morning and stayed until dark in the evening to make maximum use of the limited daylight. MMO searching and or tracking and tag boat support continued as long as possible. Often making use of the ship's crew to steer HUS in a position to make optimal use of the light. In this first two weeks, MMO effort during daylight and especially during the tagging phase was intense given that part of the team was either preparing tags or tagging out at sea. However, during nighttime when no tags were on, there was no MMO effort needed at all. During daytime and when the Socrates team was available, they provided support on the observation deck. Weather conditions in October and November where hardly hampering MMO effort, apart from one or two times when the observation deck was slippery because of snowfall or freezing rain. The ship's crew of HUS kindly provide support on these rare occasions.

Table 3.5 The table shows an overview of the total number of sightings as well as the number of cetacean species seen overall, maximum number of sightings in one day, maximum number of species seen in one day and the total number of mitigation shutdowns. BA= Balaenoptera acutorostrata (Minke whale); BB=Balaenoptera borealis (Sei whale); BP=Balaenoptera physalus (Fin whale); MN=Megaptera novaeangliae (Humpback whale); OO=Orcinus orca (Killer whale); PM=Physeter macrocephalus (Sperm whale); PP=Phocoena phocoena (Harbour porpoise).

DESCRIPTION	COUNT	COMMENTS
SIGHTINGS (TOTAL)	407	
CETACEAN SPECIES SEEN FROM OBS-DECK	7	(00, Mn, Bp, Ba, Pp, Pm, Bb)
MOST SEEN SPECIES	200	*Orcinus orca*
MAX NUMBER OF SIGHTINGS IN ONE DAY	60	27/10/2023
HIGHEST NUMBER OF SPECIES SEEN IN ONE DAY	5	17/10/2023
MITIGATION SHUTDOWNS	11	6 within the same experiment

Visual effort on the HUS observation deck was reduced during the second half of the trial as the focus on tagging efforts moved to night times when the herring fishery was actively fishing. The majority of the fishing effort took place during periods of dusk or darkness when visual effort was of little value. Full visual effort was still in place for mitigation purposes during the experimental phases while an active sonar source was turned on, with a monitoring zone of 500 m implemented. Sightings were made using hand-held binoculars with reticles or estimates by eye. The big eye binoculars were not used during mitigation. Sightings were entered into the IFAW Logger software. Whale locations were calculated using the position and gyro heading of the vessel, and the range estimate and bearing measurement of the sighting. When reticles could not be used to make a sighting, e.g., due to poor weather conditions (sea state, swell, showers) or when land was visible on the horizon, the ranges were estimated by eye. Of all range estimates, the majority were reported as estimates by eye (87.73% for the first two weeks, 95.91% for the second two weeks, and 92.87% for the entire month combined), although these were often guided by binocular observations. The location of any fixed fishing gear was also logged in logger for added safety of the vessel.

In periods of darkness, the Pulsar Merger XP handheld night vision binoculars (herein referred to as “Mergers”) were used to ensure mitigation could continue without interruption. The Mergers were set to the red monochrome color mode with the smallest magnification for the best images of whales. Whales could be clearly seen, as well as birds and deployed fishing gear. It was difficult to estimate exact distance while using the Merger, so the area monitored during periods of darkness was likely larger than the standard 500 m used for mitigation in periods of daylight. If animals came within the mitigation zone, this was immediately communicated to the CO or XO on the bridge, who made the executive decision to turn off the sonar source if the animal was in danger of getting within the 100m shut down range. The source was not turned back on until it was confirmed by the MMOs on the observation deck that the animals were behind the vessel or outside of the danger zone. There were 11 mitigations shutdowns over the course of the 4 experiments, typically lasting 2-4 min. The minimum shut down time was 1:30 min and the maximum shut down was 5:30 min. The harmonics test on 30th October was also delayed by 10 minutes due to orcas close to HUS at the desired start time.

To summarize the visual effort, the first and second half of the 3S-2023 trial were significantly different and hence the MMO effort was as well. However, in both parts of the trial, the lead MMOs proposed the rotation schemes for their respective watch shifts in coordination with the CO or XO. This was always done taking the availability of tag team into account and being flexible while needed.

3.4.1 Visual sighting data management

The Logger program works with an Access database to log positions, monitoring effort, tracking and sightings. Data is entered in real time from the observation deck, and a backup is created at the end of every observer rotation. Data is then quality assured and checked by the lead MMOs. The data for the effort, sightings, re-sightings, VHF detections, and overall comments are transferred from Access into Excel, and each line is individually checked. For example, any corrections entered into the comments section are entered into the corresponding line of data, and a note of the correction is entered into that individual data point’s comments section inside brackets. Additionally, the accuracy of the reticles versus distance compared to the conversion sheets for big eyes and binoculars is checked individually. A full summary of the logger procedure can be found in the 3S-2019 cruise report (Kvadsheim et al. 2020).

An experiment timeline was also created based on event data entered into logger. All on-effort events for each day were entered into an excel sheet, with the timing and data (UTC) from the effort form/comments. Experiment timing and timing of tag on/off can also be checked with the Socrates log or the tag data itself, respectively.

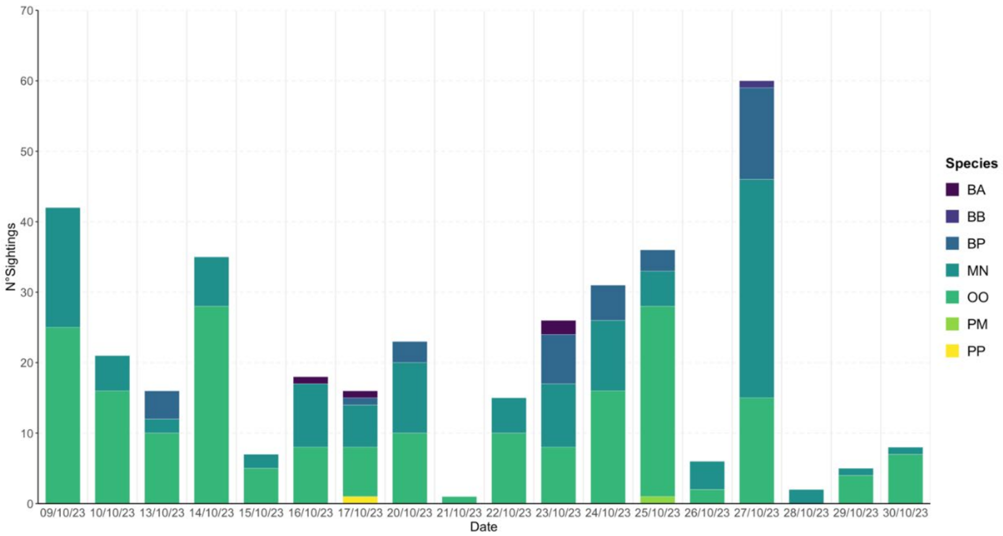


Figure 3.22 Overview of sightings per day over the entire cruise. BA=Balaenoptera acutorostrata (Minke whale); BB=Balaenoptera borealis (Sei whale); BP=Balaenoptera physalus (Fin whale); MN=Megaptera novaeangliae (Humpback whale); OO= Orcinus orca (Killer whale); PM=Physeter macrocephalus (Sperm whale; PP=Phocoena phocoena (Harbour porpoise).

3.5 Passive and active acoustic effort

3.5.1 Passive acoustic detection and tracking

The Delphinus acoustic array was towed a limited number of times during the first week of the trial, before we started working around the fishing fleet. In total Delphinus was deployed 3 times for a total duration of 11 hours.

During repair efforts of the Socrates source the depth sensor power connecter was accidentally removed and touching ground. This probably led to a failure in 5 of the 16 Delphinus MF hydrophones as observed during the 3rd Delphinus deployment. This means that the Delphinus array performance in the LF band was severely degraded. Since 2017 the UHF data was already severely degraded due to significant electronic interference.

Table 3.6 Effort table for deployment of the Delphinus array during 3S-2023

Exp Name	Date (start time)	Start Time (UTC)	Stop Time (UTC)	Duration [HH:MM]	Summary
CEE23001	09-10-2023	06:45	09:20	02:35	Search for KW
CEE23002	12-10-2023	12:00	18:44	06:44	Search for KW in fjords
CEE23003	13-10-2023	05:00	05:18	00:18	Search for KW, broken channels [7, 12, 13, 14, 15]
CEE23004	13-10-2023	05:30	06:43	01:13	Search for KW

During this cruise it appeared that no array was needed to find target animals, when working in this season and working together with the fishing fleet. This in combination with the technical issues with the array raises the question if the Delphinus array would be an (essential) asset for the scheduled 3S-2024 cruise.

3.5.2 Socrates Source

The Socrates II source was tested in the first weeks of the trial and used at the successful exposure experiments in the third and fourth week of the cruise.

During low frequency (LF) harmonics testing at the start of the trial, the LF transducer stopped working at an audible level. Socrates was recovered and all separate parts of the system were tested in the next days. The amplifiers and deck cable worked correctly. The tow cable showed some damage of short circuit near the connector to the pressure box in de Socrates source. The end of the tow cable was therefore replaced by a part of a spare deck cable that was available. After that the source did still not produce sound at the expected level. The source was audible at deck, but the source level was far too low for exposure experiments.

Simultaneously a second and identical source of the Royal Netherlands Navy was shipped from Spain, Socrates III. Upon arrival in Tromsø it also showed short circuit damage, this time between the connectors of the pressure box and the transducer. The short circuit had caused completely melted connectors. Thus, the source failed inspection and was therefore not deployed.

After extensive consultation it was decided to use the mid frequency (MF) transducer of the original Socrates II source. After repairing the tow cable this transducer was working as expected. This resulted in higher frequencies and lower source levels, but this was regarded to produced meaningful results, especially for killer whales, that have higher hearing sensitivity at the MFAS frequencies compared to LFAS, compensating for the lower source level of the transducer.

Table 3.7 Source characteristics of the Socrates source used during 3S-2023

	Frequencies [Hz]	Source level [dB]
LF CAS	1300-2000	201
LF PAS	1300-2000	214
MF CAS	4000-6000	183
MF PAS	4000-6000	197

Before the trial the amplifiers of the Socrates II source were replaced. A duration test was planned in the first days. Due to the failure of the source, these tests were postponed to a few days later. During the endurance tests, the transformer of the high-frequency source appeared to become very hot. After consultation with the manufacturer, it was decided to carry out more extensive endurance tests and monitor the temperature. The transformer appeared to easily reach a temperature above 70 degrees Celsius. The maximum source levels of the MFAS source were therefore adjusted downwards by 2 dB and active ventilation was added to the amplifier rack during further experiments. This ultimately provided sufficient temperature suppression for longer duration CAS and PAS transmissions.

Table 3.8 Effort table for deployment of the Socrates source during 3S-2023

Date (start time)	Exp Name	Transmission	Start Time (UTC)	Stop Time (UTC)	Summary
07-10-2023	Harmonics LF	CW-Harmonics-Test	14:19	17:04	Harmonics testing including Ram-pup and duration test of amplifiers; 16:30 no audible signals from Socrates
11-10-2023	Testing	HF_test	04:42	10:16	Testing Socrates HF transducer and amplifiers due to overheating transformer at up to 199dB
20-10-2023	CEE23006	HF-CAS_FullPower	10:10	16:46	Exposure experiment
23-10-2023	CEE23008	HF-PAS_FullPower	05:45	13:45	Exposure exp; reduced power 10:50-11:14 due to overheating problems
25-10-2023	CEE23009	HF-CAS_FullPower	07:20	15:20	Exposure experiment
27-10-2023	CEE23010	HF-PAS_FullPower	08:28	16:28	Exposure experiment
30-10-2023	Harmonics HF	HF-Harmonics-Test	14:45	15:13	Harmonics HF testing including rampup

3.6 Tagging effort

Killer whales and humpback whales aggregate in great numbers to feed on overwintering herring in the operation area between October and February. We knew from previous 3S-effort that tagging killer whales in this area is very difficult. It was therefore part of the plan to work in the area/period where both killer whales and humpback whales feed around herring purse seine fishing vessels. The experience from our baseline studies in this area is that animals are much easier to approach and tag when they are in this intense feeding mode.

3.6.1 Tagging effort 1 – no success during “wild tagging”

Suction-cup tagging was attempted in two very different scenarios over the course of the trial. In the first two weeks of the trial, there was little fishing activity, and the fishing fleet worked very far offshore where the weather at the time was too rough for us to work in. We were therefore left with the option to search for whales in the coastal and in-shore areas. We did find whales, but not in large numbers. Tagging was attempted during daylight in what we called “wild tagging” scenario on whales swimming freely and not interacting with the fishing vessel. It was found that killer whales could not be approached closely enough for any mixed-DTAG^{++} attempts using the pole method. This was the case even with poles lengthened to 7m by adding another pole section, and many hours of dedicated boat approached over different days. Because we found that it was not feasible to attach tags using poles during “wild tagging”, a decision was made to attempt tagging using the ARTS system. After a few hours of effort, an attempt to attach a mixed-DTAG^{++} using the ARTS system was made – the attachment was not successful as the tag struck the edge of the dorsal fin and bounced away. Careful inspection of the tag indicated that it suffered no damage from the missed tagging attempt. In another instance the ARTS tagger conservatively refrained from launching the tag on a relatively nearby animal to avoid potential tag damage. Though we had limited effort with the ARTS system, we conclude that use of the ARTS deployment system does make tagging attempts more feasible in the "wild tagging" scenario. This conclusion matches our understanding following the 3S1 research effort, during which the ARTS system was initially developed specifically to aid tagging free swimming killer whales in open water.

Since numerous attempts to deploy the mixed-DTAG^{++} to free swimming killer whales using the handheld pole during the first two weeks were unsuccessful, we focused on deploying the Splash limpet tags. This was successfully achieved in the first half of the trial as planned (more in section 3.8).

3.6.2 Tagging effort 2 - great success tagging near purse seine fishing vessels

In the second half of the trial, the herring and fishing fleet moved closer to the coast, and we switched to almost exclusively tagging round fishing vessels. We immediately found that it was highly feasible to approach whales for tagging near fishing boats, as we had specified in the cruise plan. Suction cup tags were successfully attached to killer or humpback whales during almost every deployment of the tag boat when tagging effort was near purse seiners.

In accordance with Norwegian law small boats are for safety reasons not allowed to approach closer than 0.2nmi from fishing vessels actively engaged in purse seine fishing. However, research is under exemption from this rule, but we still need permit from the fish boat captains to approach. During the trial, our tag boats were checked by both the Coast Guard and Fishery Directorate offshore service, to make sure they followed the rules. Working to tag around fishing vessels thereby required careful monitoring of the activity of the fish fleet.

Figure 3.23 Left: MOBHUS working around the net of a fishing vessel in the dark. Right: a humpback whale feeding on herring along the purse seine nets (photos C. Reesor).

Figure 3.24 Left: Attempts to tag a killer whale with the mixed-DTAG++ using handheld pole (photo R. Roland). Right: Photo of a Mixed DTAG++ on a killer whale taken during daytime tagging. Note the red light on the camera unit of the tag (photo G. Sato).

During the trial we made contact with more than 70 fishing vessels in the operation area. Responses from the fishing vessels were almost exclusively positive towards our research. During our tagging effort we approached about fifty percent of these vessels while they were pumping the herring catches from the purse seine nets into the fishing boat. The peak of this fishery is normally during dusk and dawn, when the herring shoals are dense and migrates closer to the surface. However, other factors like the level of overcast and the moon cycle plays a role in the vertical migration of the herring. During the trial we experienced active fishing often extended from the afternoon until early morning. The marine traffic Automatic Identification System (AIS) were used to monitor the fishing vessels activity (Figure 3.25). When the nets are set, they use navigation lights to indicate restricted maneuverability. This means it's time to get the tags and the tag team ready. In this stage the fishing vessel has no work lights on deck because the herring would respond to light. It usually takes about 1 hr. before they have the nets closed and turn on deck light. At this time the tag boat should be ready on the water and could start approaching the vessel to tag in the light of the fishing vessel (Figure 3.23). Thermal nighttime binoculars were helpful in following the fishing process from the bridge of Sverdrup. Simultaneously, we monitored other fishing vessels from the bridge of Sverdrup by use of the AIS system (Figure 3.25), in order to guide the tag-boat team on to the next fishing vessels closing their net and ready for the pumping operation. The fishing vessels always work the nets on the Starboard side, thus the tag-boat team often waited in the dark at Port side. When the deck light was switched on, they could move closer and tag whales that was feeding on spills and leftover from the fishery. In this situation it was possible to deploy mixed-DTAG++ both to killer whales and humpback whales using the hand pole. The timeline of the pumping operation is dependent of the size of the fishing vessel and the volume of the herring catch, and varies from 30 minutes to 2 hours, most often around a 1-hour operation. We experienced that the light was favorable for our tagging operation especially from some of the larger vessels, and in some cases, we also had help with extra light from some of the vessels.

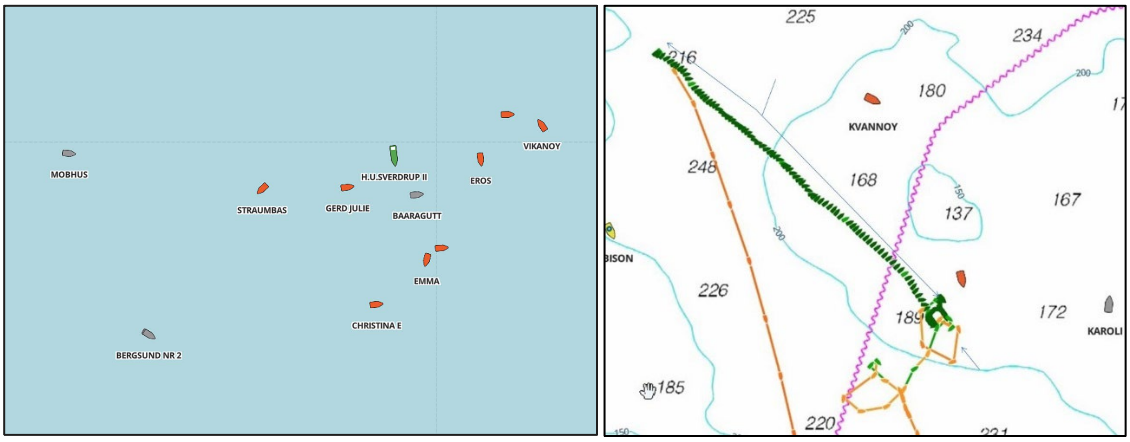


Figure 3.25 Left: screenshot of AIS display on the RV HU Sverdrup. Our own position is indicated in green, the tag boat (MOBHUS) in grey and numerous fishing vessel around us in red. Right: detailed track of a fishing vessel catching herring. The yellow line shows the vessel searching for fish with their fishery sonar before setting the purse seine net around the fish school. This takes about one hour, before they start drifting (green track) during the process of pumping the herring from the net into the boat. The pumping process is the best window for us to approach the vessels to tag, because the ship is stationary and have deck lights on. The straight yellow track shows the vessel speeding up after finishing the pumping period. Two other fishing vessels are searching in the same area, in addition to the coastguard vessel KV Bison controlling the fisheries.

3.7 Mixed-DTAG^{++} data collection

In total, 18 mixed-DTAG^{++} were attached to killer whales (N=13) or humpback whales (N=5) whales over the period 17-30 October, recording a total of 245.6hrs of on-animal data (162.5 hrs. with killer whales, 83.1 hrs. with humpback whales). All tags were recovered quickly after detachment, and no tags were lost during the experiment. Tag recovery was greatly aided by both ARGOS and GPS-Goniometer receptions received after tags detached from whales. In some cases, the GPS locations alone could be used to locate the floating tag using Sverdrup, but in most cases, tags were recovered from the tag boat using the VHF beacon on the tag.

3.7.1 Suction cup retention times in relation to experimental timeline

Of the 18 deployments, 5 detached in less than 1 hr. after tag placement Table 3.9; Figure 3.26). Such very short deployments are not desirable but are not too costly to the field effort as the detached tags can be quickly recovered by the tag boat team and deployed again. Because the number of obtained data from such deployments is limited (and possibly influenced by ongoing tag boat activities), those data are not used further for analyses to support the 3S4 study.

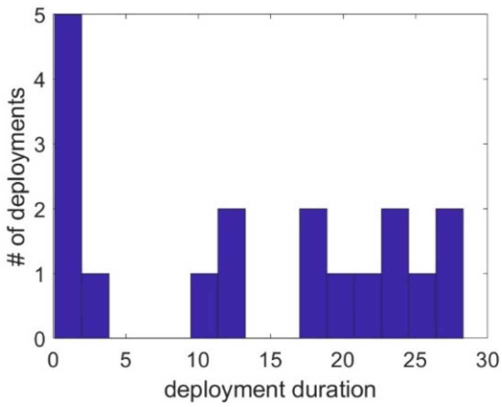


Figure 3.26 Durations of all 18 mixed-DTAG^{++} deployments during the 3S-2023 trial. 5 tags detached after 1hr or less, 4 had durations 1-13 hrs., and 9 had durations >17 hrs.

Of the 13 tags that remained attached for more than 1 hr., 4 (~30%) detached after being attached for 1-13 hours duration. These deployments all contain useable baseline periods before sonar exposures started, and one record Oo23_299b contained the initial part of the sonar exposure period.

The remaining 9/13 deployments (70% of tags >1hr attachment) remained attached to whales for a duration of 17.7-28.3 hrs. (average 22.9 hrs.), which is long enough to complete the full experiment cycle plan. Indeed, the CEE experimental cycle was completed for 6 of these 9 tagged animals.

In conclusion, attaching suction cup tags was highly effective using the 90° pole system (chapter 2.2) so long as tagging was done in association with purse seine fishing vessels (chapter 3.6). Half (9/18) of all tag deployments remained attached long enough for the full 3S4 experimental cycle to be completed. Thus, attachment durations were sufficiently long for the 3S4 experimental cycle. In contrast tagging using poles was not feasible in the absence of purse seine fishing vessels ("wild tagging" scenario). ARTS tagging is likely to be more feasible in the "wild tagging" scenario, so it is recommended to be used more in 2024 if tagging in that scenario is required. However, we should keep in mind that tag placement is still very critical for tag performance.

3.7.2 Mixed-DTAG^{++} data quality

The Mixed-DTAG++ data recordings were generally of high quality, with only a few issues noted. Core unit 311 was found to have noisy pressure data, so pressure data from those deployments will need to be replaced by the 24hr backup data recorded by the Little Leonardo dataloggers. One deployment (oo23_297b) had no GPS locations logged. GPS positions for this deployment are available via Goniometer receptions and some GPS locations were successfully transmitted to the ARGOS satellite system. Except for oo23_297b, GPS positions were logged consistently, and GPS positions relayed using the Goniometer system was highly effective at enabling us to complete our experimental program.

The Little Leonardo logger recorded depth and 3-axis acceleration data for 24hrs as designed. As noted above these data serve as a valuable backup in the case the DTAG core unit depth data are faulty. The start time of the data recordings is noted in Table 3.10. A variable number of video files was recorded for each deployment, and no video was recorded for 3 deployments (oo23_292a, oo23_299b, and oo23_303a). We found that the start time and duration of the video recordings did not always match what was expected based on the programming. This fault means that more videos were recording during dark hours than planned and could mean that some video sequences will be challenging to synchronize with the DTAG recordings. This problem has been addressed with the manufacturer (Little Leonardo), who identified some software issues with these newly released loggers. We expect that all issues will be addressed prior to the 3S-2024 research trial.

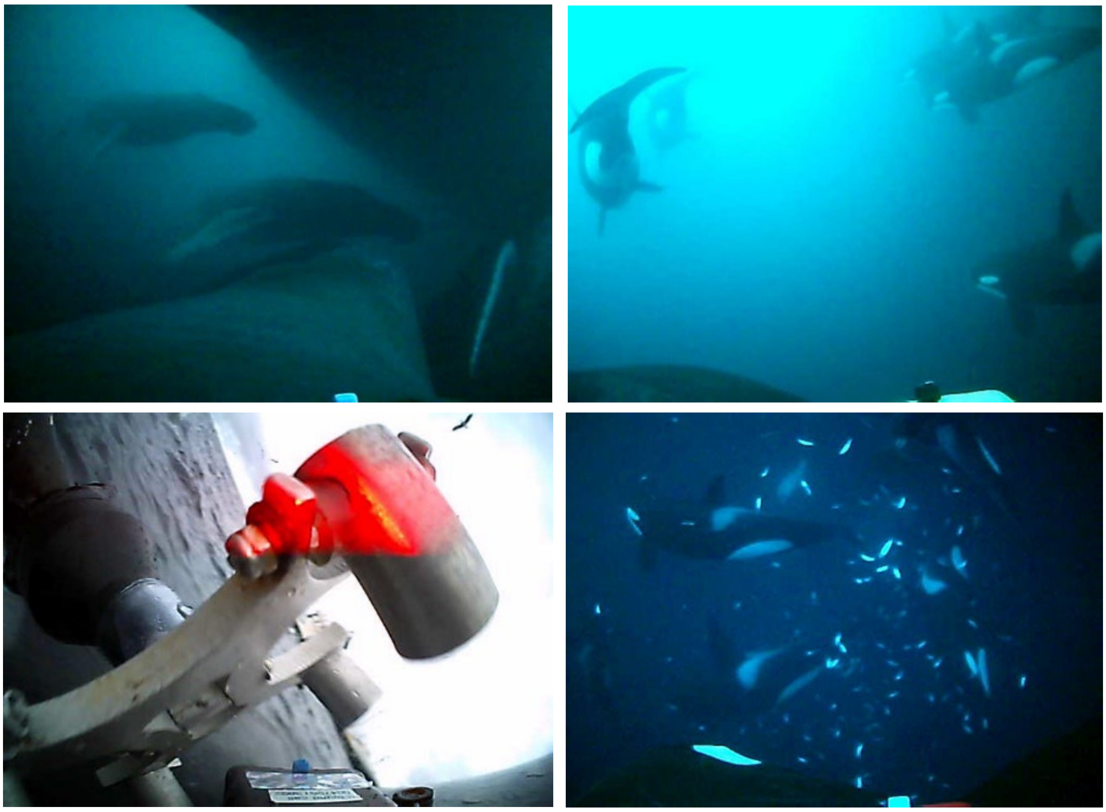


Figure 3.27 Screenshots from the recordings of the Little Leonardo camera unit on the mixed-DTAG^{++} showing social interactions, prey field interaction and tagger interactions. Upper left mn23_299a, upper right oo23_299a, lower left oo23_295a and lower right oo23_302a.

Table 3.9 DTAG deployment table for the 3S-2023 trial.

Date	Deployment ID / method	DTAG start time (UTC)	Tagon time and location	Resp	Hrs on animal	Tag type	GPS / ARGOS	Why released	Exposure	Comments
17.10 .2023	oo23_290a Pole	N/A	16:49 UTC N/A	0	0.5	Mixed-DTG++ Scooby (C302)	215144	Released early, core unit malfunction	No	Releases appeared to have started burning immediately, and no files were recorded on DTAG, attachment just above eyepatch, near a purse seiner
17.10 .2023	oo23_290b Pole	17-Oct-23 18:51:59	19:04 UTC N/A	0	0.4	Mixed-DTG++ Elmo (C317)	161599	Released early	No	Briefly deployed (2s) on other whale at start, attachment behind dorsal fin, near a purse seiner
19.10 .2023	oo23_292a Pole	19-Oct-23 21:26:21	21:36 UTC 70.29322N 20.98697E	0	0.2	Mixed-DTG++ Elmo (C317)	161599	Released early	No	Attachment on lower dorsal fin, near a purse seiner
19.10 .2023	oo23_292b Pole	19-Oct-23 21:37:29	21:38 UTC 70.29322N 20.98697E	0	21.1	Mixed-DTG++ Scooby (C311)	215244	Released early	YES (CAS 1)	Noisy DTAG pressure data, attachment in front of dorsal fin, near a purse seiner

20.10 .2023	mn23_293a Pole	20-Oct-23 00:35:00	00:35 UTC 70.30302N 20.95817E	0	19.6	Mixed-DTG++ Homer (C330)	215143	Released early	YES (CAS 1)	Attachment quite high and forward on body, directly above pectoral fins, near a purse seiner
22.10 .2023	oo23_295a Pole	22-Oct-23 08:19:46	08:20 UTC 70.32043N 20.95468E	1 minor flinch, quick dive	26.8	Mixed-DTG++ Scooby (C311)	215144	Released early	YES (PAS 1)	Large adult male, attachment on lower dorsal fin, near a purse seiner with net full of fish (>200 Oo nearby, >4 Mn)
22.10 .2023	oo23_295b Pole	22-Oct-23 19:42:39	19:43 UTC 70.29518N 20.84145E	1 tail slap	24.7	Mixed-DTG++ Elmo (C317)	161599	Released as programmed	YES (PAS 1)	Adult female, tagging footage (+ tail slap) can be seen in GoPro footage, feeding near a herring purse seiner, attachment high on body, in front of dorsal fin
24.10 .2023	oo23_297a Pole	24-Oct-23 20:34:39	20:35 UTC 70.54438N 21.43033E	0	1	Mixed-DTG++ Scooby (C311)	215144	Released early	No	Adult male, feeding near herring purse seiner, many Oo and Mn around, attachment in front of dorsal fin

24.10 .2023	oo23_297b Pole	24-Oct-23 20:26:58	20:27 UTC 70.5424N 21.43015E	1 quick flinch	24.5	Mixed-DTG++ Homer (C330)	215243 No data recorded on GPS logger	Released as programmed	YES (CAS 2)	Adult male, feeding near herring purse seiner, many Oo and Mn around, attachment at base of dorsal fin, VHF antenna a little bent upon recovery, no data recorded on GPS logger, but remote download (from ARGOS server) and goniometer worked normally
26.10 .2023	mn23_299a Pole	26-Oct-23 06:54:56	07:02 UTC 70.44802 N 21.66422 E	0	10.75	Mixed-DTG++ Elmo (C317)	161599	Released early	No	Attachment high up on body, right below dorsal fin
26.10 .2023	oo23_299a Pole	26-Oct-23 22:43:19	21:57 UTC 70.5527 N 21.55147 E	0	18.8	Mixed-DTG++ Marge (C330)	183278	Released early	YES (PAS 2)	Attachment on side in front of dorsal fin, antennas down
26.10 .2023	oo23_299b Pole	26-Oct-23 22:12:13	22:16 UTC 70.5527 N 21.5702 E	1 quick dive	12.2	Mixed-DTG++ Simba (C329)	161601	Released early	YES? (PAS 2)	Attachment very low on right side, antenna up but no beeps

27.10 .2023	mn23_300a Pole	27-Oct-23 00:17:33	00:17 UTC N/A		<0.1	Mixed-DTG++ Scooby (C311)	215144	Released early	No	Tag stayed on for a single dive then came off, doesn't seem to have stuck properly
28.10 .2023	oo23_301a Pole	28-Oct-23 17:11:20	17:11 UTC 70.5012 N 21.3784 E	1	12	Mixed-DTG++ Elmo (C317)	161599	Released early	No	Attachment high up on body, just in front of dorsal fin, feeding near herring fishing boat
28.10 .2023	mn23_301a Pole	28-Oct-23 19:55:22	19:55 UTC 70.4495N 21.2910E	0	28.3	Mixed-DTG++ Simba (C329)	161601	Released early	No	Attachment high up on body, between head and dorsal fin, antennas backwards, feeding near herring fishing boat
29.10 .2023	mn23_302a Pole	29-Oct-23 02:44:02	02:44 UTC 70.50345N 21.48357E	0	24.3	Mixed-DTG++ Marge (C330)	183278	Released as programmed	No	Attachment high up on body, below dorsal fin, feeding near herring fishing boat
29.10 .2023	oo23_302a Pole	29-Oct-23 17:13:30	17:24 UTC 70.48196N 21.30765E	1	17.7	Mixed-DTG++ Elmo (C317)	161599	Released early	No	Attachment high on body, in front of dorsal fin, feeding near herring fishing boat

30.10 .2023	oo23_303a Pole	30-Oct-23 05:35:33	05:35 UTC 70.5722N 21.54442E	1	2.6	Mixed-DTG^{++} Scooby (C311)	215144	Released early	No	Attachment in front and to the side of dorsal fin, antenna down, feeding near herring fishing boat, cable tie holding core unit ripped through the casing, wire tore off from a release pin

Note: Deployment oo23_297b started before oo23_297a, and oo23_299b started before oo23_299a.

Table 3.10 Data recording details for the Little Leonardo loggers carried in the mixed-DTAG++. Note the Start Time differs from the Dtag deployment times as the Little Leonardo tags have a delay timer from when they are manually triggered in the lab.

Deployment	Logger ID	Experiment?	10+ hour deployment?	Video (Number of Files)	Start Time (UTC) Data and 1st video	Interval Settings	Duration of Video
oo23_290a	23006	NO	NO	YES (7)	17-Oct-23 ~17:01	0	3:28:32
oo23_290b	23005	NO	NO	YES (7)	17-Oct-23 ~20:07	0	3:25:22
oo23_292a	23005	NO	NO	NO	N/A	N/A	N/A
oo23_292b	23006	CAS 1	YES	YES (26)	19-Oct-23 22:49:41	60	4:00:15
mn23_293a	23007	CAS 1	YES	YES (27)	19-Oct-23 23:54:21	60	3:50:10
oo23_295a	23006	PAS 1	YES	YES (9)	22-Oct-23 07:57:49	0	4:13:57
oo23_295b	23005	PAS 1	YES	YES (22)	22-Oct-23 ~20:03	60	0:21:36
oo23_297a	23006	NO	NO	YES (4)	24-Oct-23 19:23:54	0	1:46:15
oo23_297b	23007	CAS 2	YES	YES (28)	24-Oct-23 ~20:54	60	7:16:40
mn23_299a	23005	NO	YES	YES (16)	26-Oct-23 04:56:39	0	7:59:54
oo23_299a	23007	PAS 2	YES	YES (29)	26-Oct-23 22:42:53	60	7:46:37
oo23_299b	23008	PAS 2 (?)	YES	NO	26-Oct-23 20:59:29	N/A	N/A
mn23_300a	23006	NO	NO	YES (7)	27-Oct-23 ~21:18	60	2:59:59
oo23_301a	23005	NO	YES	YES (17)	28-Oct-23 17:16:42	60	7:05:12
mn23_301a	23006	NO	YES	YES (27)	28-Oct-23 ~20:27	60	8:13:20
mn23_302a	23007	NO	YES	YES (28)	29-Oct-23 02:24:38	60	7:28:55
oo23_302a	23005	NO	YES	YES (23)	29-Oct-23 17:00:08	60	8:29:22
oo23_303a	23008	NO	NO	NO	30-Oct-23 06:52:04	N/A	N/A

3.8 Limpet SPLASH10-F-333B satellite tag data

Wildlife Computers Limpet SPLASH10-F-333B tags, with Fastloc-GPS and depth sensors, were deployed on or below the dorsal fin using a Dan-Inject JM25-SP or LK-ARTS pneumatic tag launcher (Figure 3.28). We deployed all six tags during the first half of the cruise and thus before the first CEE (Table 3.11). Behavioural responses by the tagged whales to deployment were either brief (flinch) or not present.

Table 3.11 Limpet SPLASH10-F-333B satellite tag deployments on killer whales. All satellite-tagged individuals were males based on the size and shape of their dorsal fin.

Tag ID	Tag-on (UTC)	End date (UTC)	Decimal PTT	Hex PTT	Tagging system	Side of body	Tag placement	Animal's reaction
SAT23_1	09/10/2023 15:45	25-Nov*	36683	20313BE	DanInject	Right	Dorsal fin, 30% from base	0 no response
SAT23_3	10/10/2023 08:19	17-Oct	183276	7AC89C7	LK-ARTS	Right	Saddle patch	1 Brief
SAT23_5	13/10/2023 08:44	22-Oct	252668	5B047C7	DanInject	Left	Saddle patch	1 Brief
SAT23_2	17/10/2023 13:38	11-Nov*	36685	20313D4	DanInject	Right	Dorsal fin, base	1 Brief
SAT23_4	18/10/2023 01:33	08-Dec*	252667	5B047BE	DanInject	Right	Dorsal fin, 50% from base	0 no response
SAT23_6	18/10/2023 01:54	20-Oct	252669	5B047D4	DanInject	Left	Dorsal fin, base? Suboptimal angle	0 no response

**Tag transmitted beyond the end of the cruise.*

Figure 3.28. Photographs of the satellite tag on the body of the whale shown in chronological order (from left to right): SAT23_1, SAT23_3, SAT23_5, SAT23_2, and SAT23_4. The last tag (SAT23_6) was attached in the night and not photographed then nor later.

The satellite tags were used with at least four objectives in mind: 1) To guide us to new study subjects for mixed-tagging, 2) To understand the larger-scale movement patterns of killer whales in the study area, including interaction with herring fishing vessel, 3) To understand diurnal patterns in their behavior, and 4) To document potential behavioral responses to sonar of non-focal animals. The tags worked as intended with regards to objectives 1-3, but whether it is possible to measure responses is still to be evaluated.

A quick look at the satellite tracks suggested two areas of higher use within the study area: one roughly at the entrance of the Kvaenangen Canal in the southeast and another one offshore to the northwest at Lopphavet (Figure 3.29). Whales were often associated with purse seine fishing vessels during the night but also spent time in areas without fishing during night and day and occasionally in areas with multiple trawlers. Diurnal patterns were apparent in the dive profiles in certain periods; for example, in the first week of deployment SAT23_1 (PTT 36683; Figure 3.30).

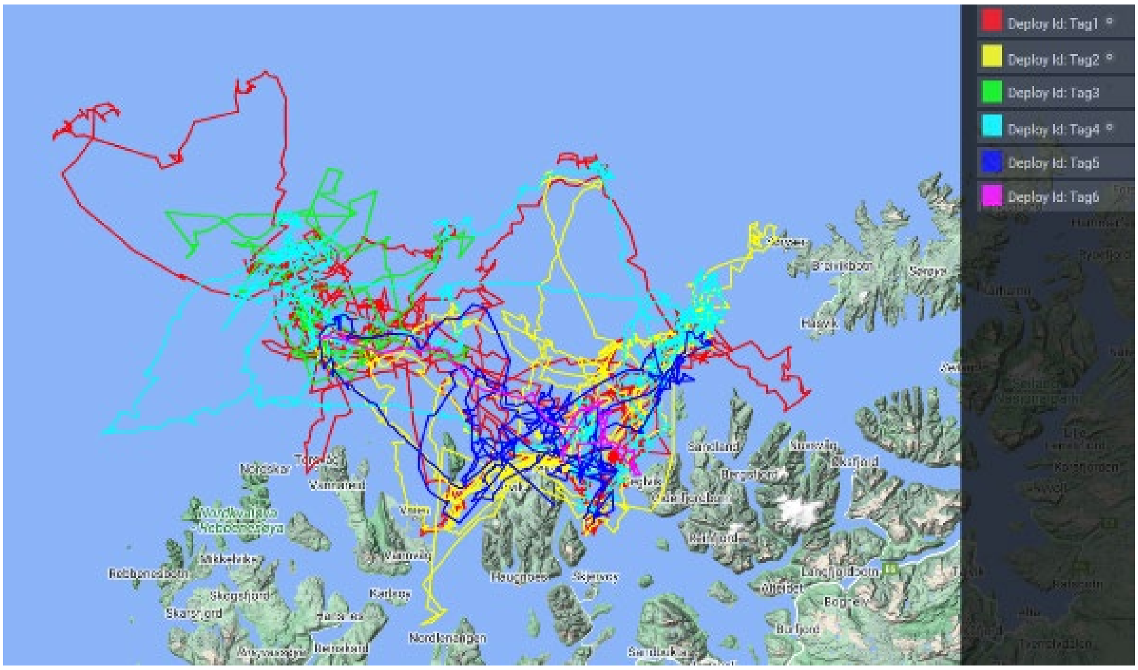


Figure 3.29 Tracks of the six satellite-tagged whales for the duration of the 3S-2023 cruise period. Tracks consist of a combination of Fastloc GPS and ARGOS-quality locations (all ARGOS classes except B and Z).

The SPLASH10-F-333B tags were programmed to transmit at a relatively high rate, recording/transmitting up to 4 GPS locations per hour and continuous depth timeseries data at the highest resolution available (75 s interval). The use of the ARGOS Goniometers to supplement the data received via ARGOS satellites substantially increased the total data coverage (by ~30% to 300% depending on the deployment). Data quality was strongly correlated with tag placement and shooting angle, with the three tags that attached to the dorsal fin at a perpendicular angle providing continuous depth records for the entire trial period while less optimal tag placements resulted in shorter records with lower data rates (Figures 3.30 and 3.31) and larger positional errors.

The first four satellite tags were deployed outside of the fishing context, without purse seiners nearby, which required substantially more effort compared to the last two tags deployed on animals feeding around a fishing vessel (both were deployed quickly during the first of such events).

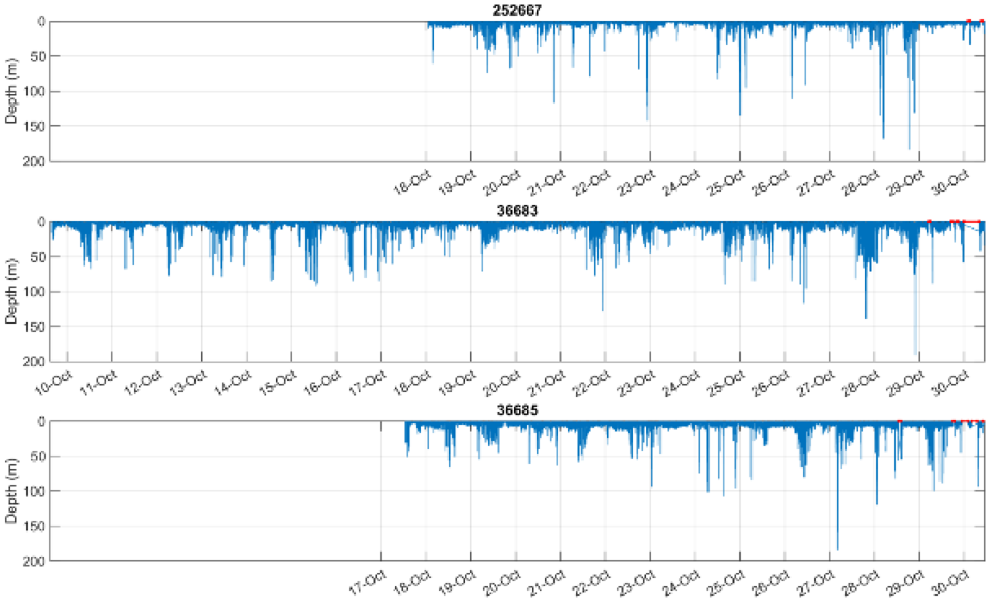


Figure 3.30 Depth data collected by satellite tags during the cruise period, shown in order of the quality of the tag placement (high on the fin is best). These tags attached to the dorsal fin and were launched at a right angle to the dorsal fin. Periods without data, i.e., data gaps, are indicated in red. The ticks on the horizontal axis mark midnight UTC.

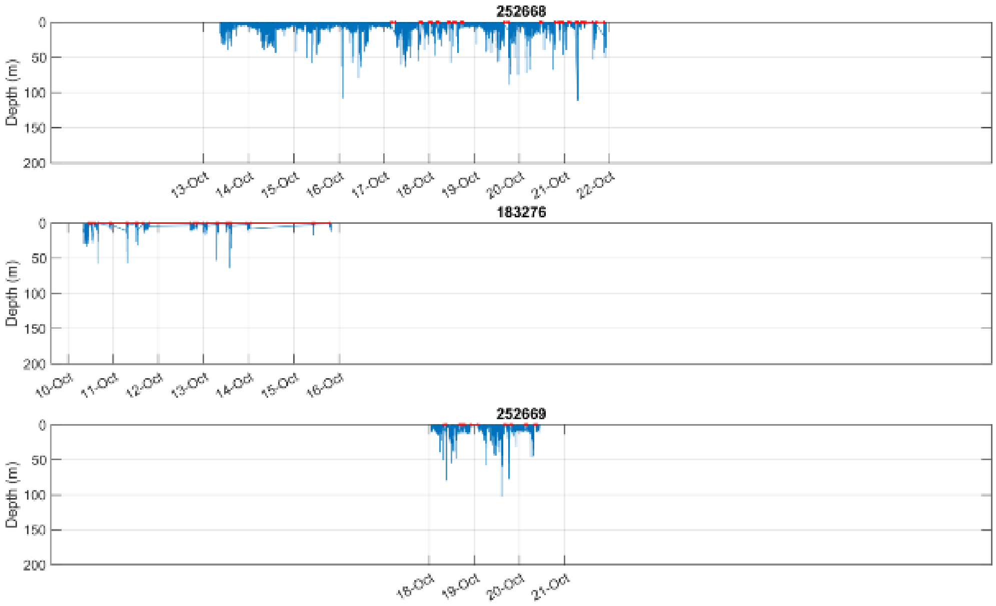


Figure 3.31 Depth data collected by satellite tags during the cruise period, shown in order the quality of the tag placement. These tags were launched at a right angle to the dorsal fin but attached in the blubber below the dorsal fin (PTTs 252668 and 183276) or were launched at a suboptimal angle (PTT 252669). Periods without data, i.e., data gaps, are indicated in red. The ticks on the horizontal axis mark midnight UTC.

3.9 Prey field mapping and sampling

When analyzing potential responses to sonar, understanding the whale's prey field in the immediate vicinity is important to consider as a co-variate that might also affect whale behavior. The choice to avoid the area or not might be influenced by the quantity or quality of available food, and these energetic choices are important when considering the responses.

Table 3.12 KONGSBERG EA640 single beam echosounder settings, their type, values and a short description used throughout the trial.

Setting Category	Setting Name	Value	Unit	Description
User	Range – Max	300	m	Current depth plus 300 m 'below' sea floor.
User	Range – Min	2	m	Start depth of the hydrophone.
User	Gain	-70	dB	Sensitivity of the echosounder's receiver.
User	Power	200	W	Power used for the transmitted sonar pulse.
Operations	Ping Mode	Interval	-	The mode of operations, set to interval
Operations	Ping Interval	600	ms	Time interval between each sonar ping.
Transceiver	Pulse Duration	0.256	ms	Duration of each sonar pulse.
Transceiver	Sample Interval	0.064	ms	Time interval between samples within a ping.
Transceiver	Power	200	W	Power of the sonar sample
Transceiver	Frequency	38	kHz	Frequency of the sonar signal.
Transceiver	Slope	0	%	Slope setting for signal processing
Transceiver	Noise Estimate	-132.5	dB	Estimated noise level in the received signal
Transceiver	Eq. Ambient Noise	298.7	dB	Equivalent ambient noise level
Transceiver	Sound Speed	1500	m/s	Speed of sound in water used for calculations
Transceiver	Ping Rate	0.8	pps	Rate at which pings are emitted
Active	TVG	20 Log	-	Setting for Time Variable Gain for log display

To characterize the prey field, the trial used a hull-mounted Kongsberg EA640 at 38 kHz, a wideband single beam echo-sounder to survey the pelagic prey area, in addition to fish sampling and bomb calorimetry of selected moribund herring to evaluate their energetics.

3.9.1 Echosounder data

Once the echosounder settings were established (8 Oct), the echosounder ran continuously until the end of the trial. The echosounder malfunctioned once for a period of a few hours before being reset and was disabled while in port for crew change. Settings, their type, values and a short description are found in Table 3.12.

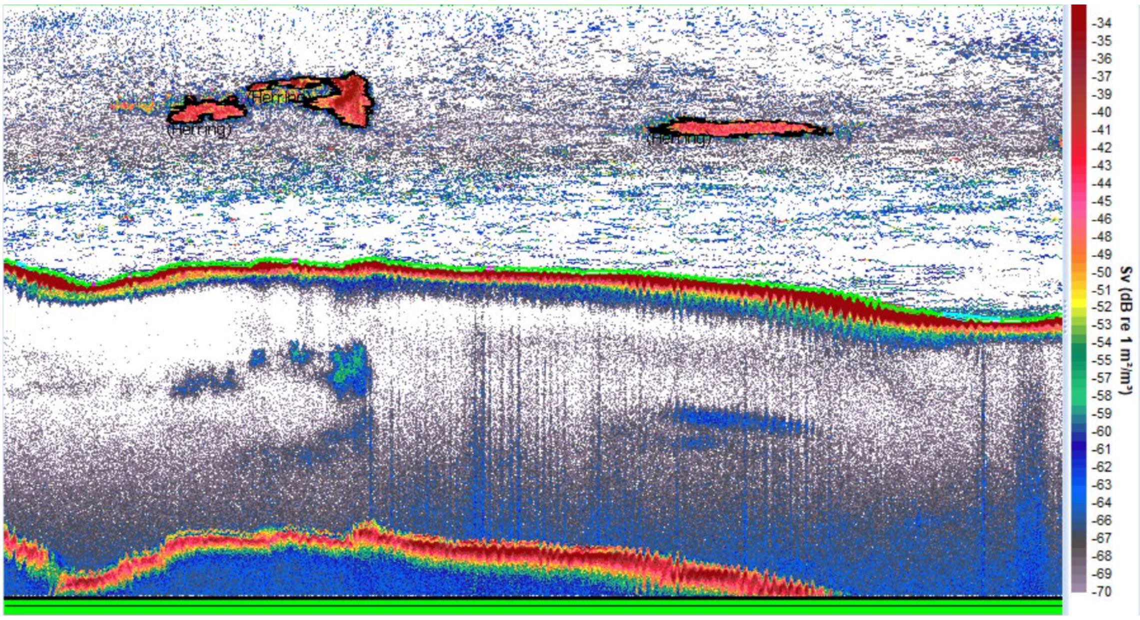


Figure 3.32 Example of raw echogram from EA600 on HU Sverdrup showing herring school detection. Bottom depth 220 m, 05:00am on the 10th October

3.9.2 Herring fish sampling

While in the tagging phase, herring were opportunistically collected in the vicinity of the commercial herring purse seiners. Collection was done from Mobhus (tagging boat) using a handheld fishing net. After collection, herring were brought onboard and processed prior to being frozen.

The sampling process onboard consisted of assigning herring with a number and date of collection, followed by measuring the length of each fish from the tip of the caudal fin to the tip of the mouth using a measuring tape. A small sample of about 3 cm of tissue was cut out just below the dorsal fin with a scalpel and then stored with the rest of the fish in a bag labeled with fish number and date of collection. Fish mass was not collected at sea, but will be measured later.

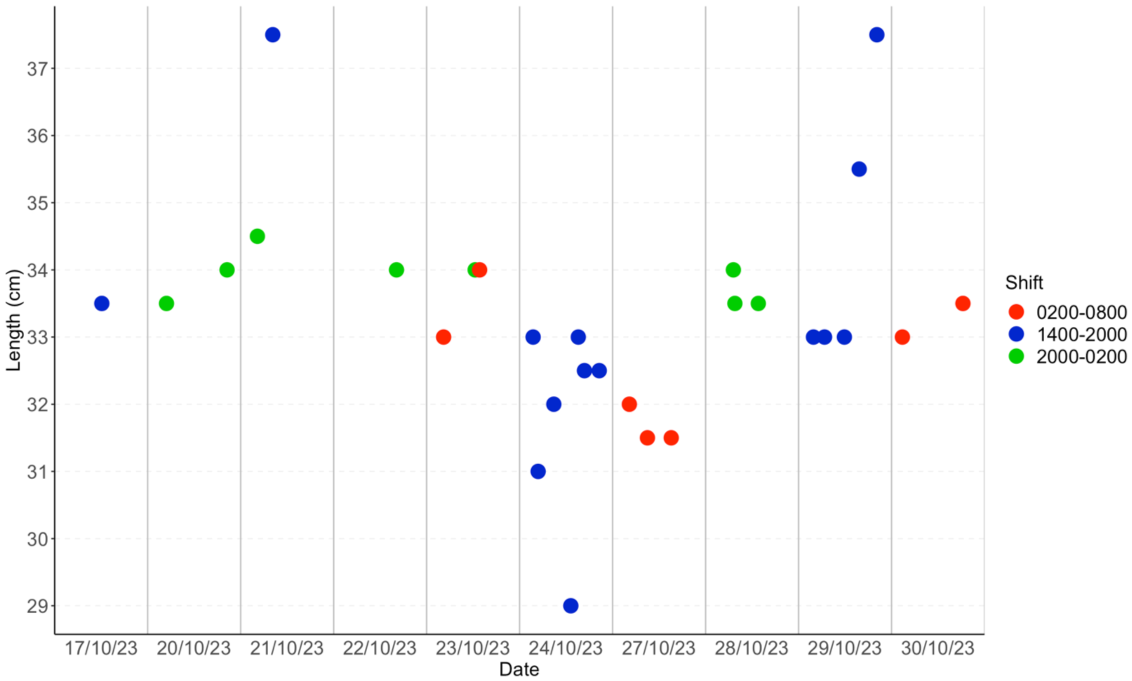


Figure 3.33 Herring sample collected per shift, showing measured length between 17th and 30th October 2023. Four six-hour shifts were used on the HUS during the trial, with watch change at 02:00 and 08:00 AM & PM. Note that no fish were collected during the 08:00 – 14:00 period due to low fishing effort and sonar mitigation or searching efforts. Dates should be confirmed once the fish are extracted from freezer storage.

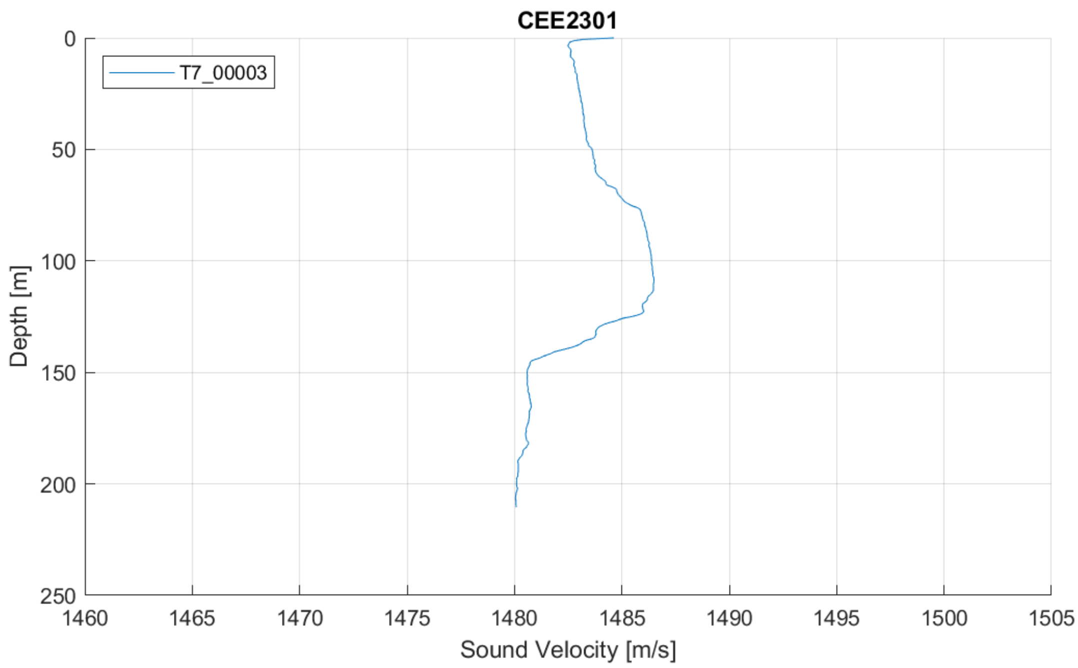
A total of 29 herring and 1 saithe (which was not taken into the analysis) were collected, measured and stored for analysis. Following the trial, samples were transported to the UK for analysis.

3.10 Environmental data

Measurements of sound propagation conditions were made in connection with the sonar exposure experiment. The mixed-DTAG++ contains hydrophones, which measured the sound levels received by the animal during the sonar exposures. However, in order to understand the response of the animal, it is important to have an idea of the overall sound field in the environment. To achieve this, Sound Speed Profiles (SSP) are used as input to sound propagation models. Temperature profiles (XBT) were collected during each exposure run using Sippican T7 XBTs from HUS. After each exposure experiment a more accurate Conductivity Temperature Depth (CTD) measurement was conducted using SAIV STD/CTD SD204 from HUS. Figures below show the measured SSP for each exposure run and the modelled propagation loss based on the measured CTD SSP using the Bellhop software.

Table 3.13 Overview of XBT and CTD cast collected during 3S-2023

Exposure Experiment	XBT/CTD name	Date & Time (UTC)	Max Depth [m]	Latitude	Longitude
Harmonics01	T7_00002.EDF	07-10-2023 15:54:46	221	68 51.26700N	16 45.18990E
CEE01	T7_00003.EDF	20-10-2023 15:09:24	250	70 13.60770N	20 51.30190E
CEE02	T7_00004.EDF	23-10-2023 06:25:03	200	70 21.96143N	21 03.38770E
	3S23 CTD01.txt	23-10-2023 20:58:41	80	70 28.94660N	20 36.33700E
CEE03	T7_00005.EDF	25-10-2023 08:55:17	200	70 18.39795N	20 39.72668E
	T7_00006.EDF	25-10-2023 13:35:26	240	70 22.89307N	19 46.53455E
	3S23 CTD02.txt	25-10-2023 23:48:59	110	70 27.57990N	19 50.06450E
CEE04	T7_00007.EDF	27-10-2023 09:16:59	200	70 31.78906N	21 27.69263E
	T7_00008.EDF	27-10-2023 15:32:34	460	70 26.54834N	21 46.84399E
	3S23 CTD03.txt	27-10-2023 21:40:59	420	70 26.88750N	21 44.04690E
Harmonics02	3S23 CTD04.txt	30-10-2023 12:30:52	190	70 26.70750N	21 18.25770E
	T7_00009.EDF	30-10-2023 15:27:15	200	70 26.82959N	21 18.15479E



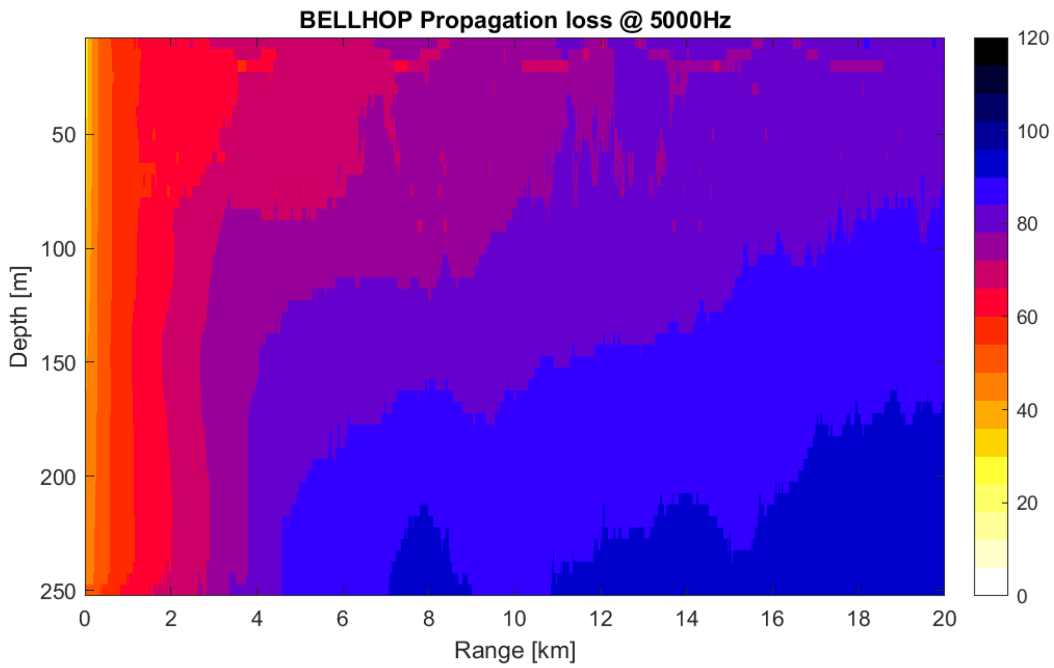


Figure 3.34 Upper panel; XBT collected during CEE I. Lower panel; Bellhop propagation loss at 5000Hz based on the sound speed profile estimated from the measured temperature profile.

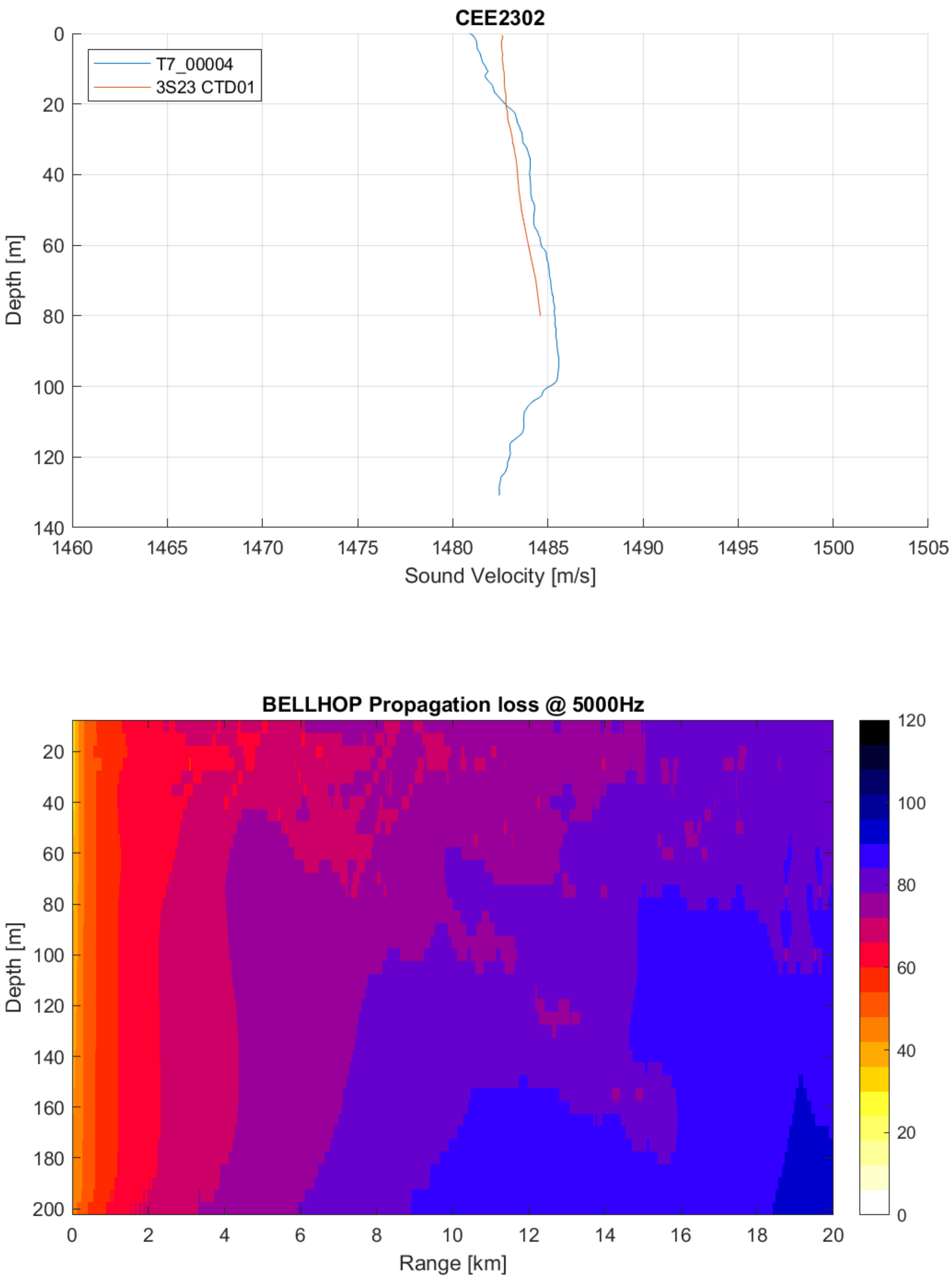


Figure 3.35 Upper panel; XBT collected during CEE I. Lower panel; Bellhop propagation loss at 5000Hz based on the sound speed profile estimated from the measured temperature profile.

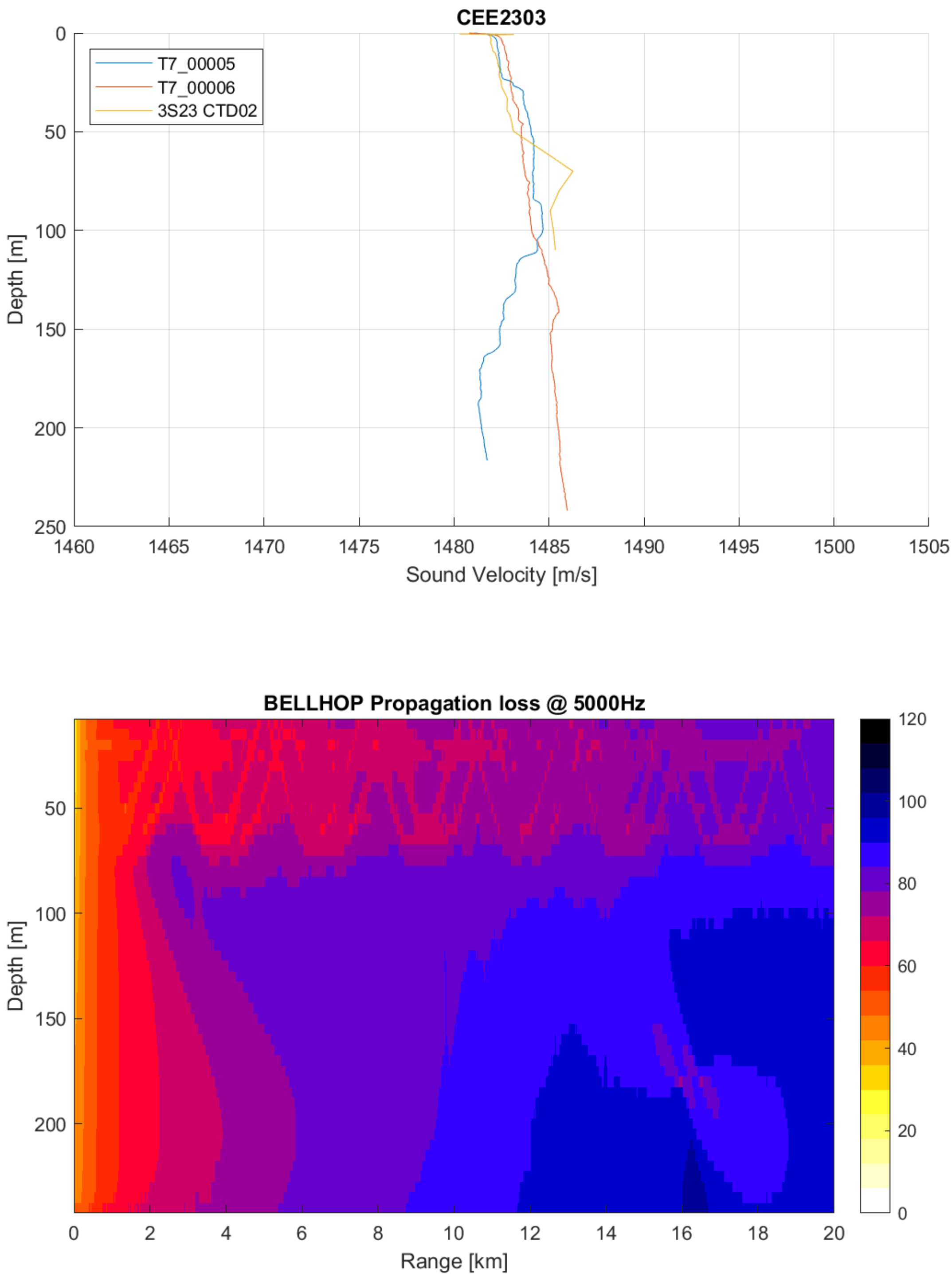
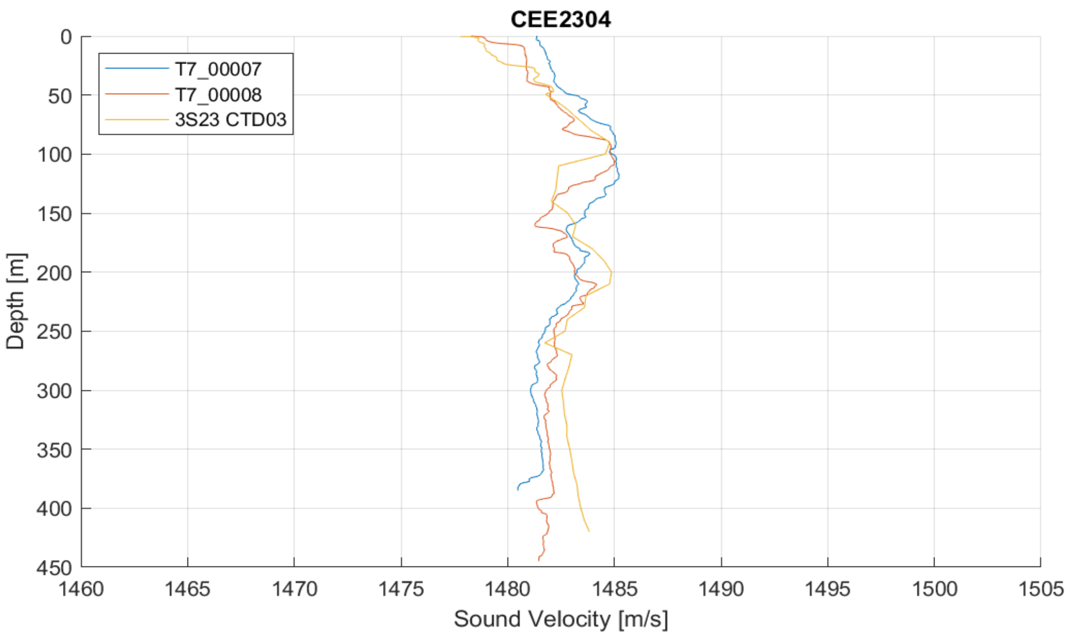


Figure 3.36 Upper panel; XBT and CTD collected during CEE II. Lower panel; Bellhop propagation loss at 5000Hz based on the sound speed profile estimated from the measured temperature and salinity profiles.



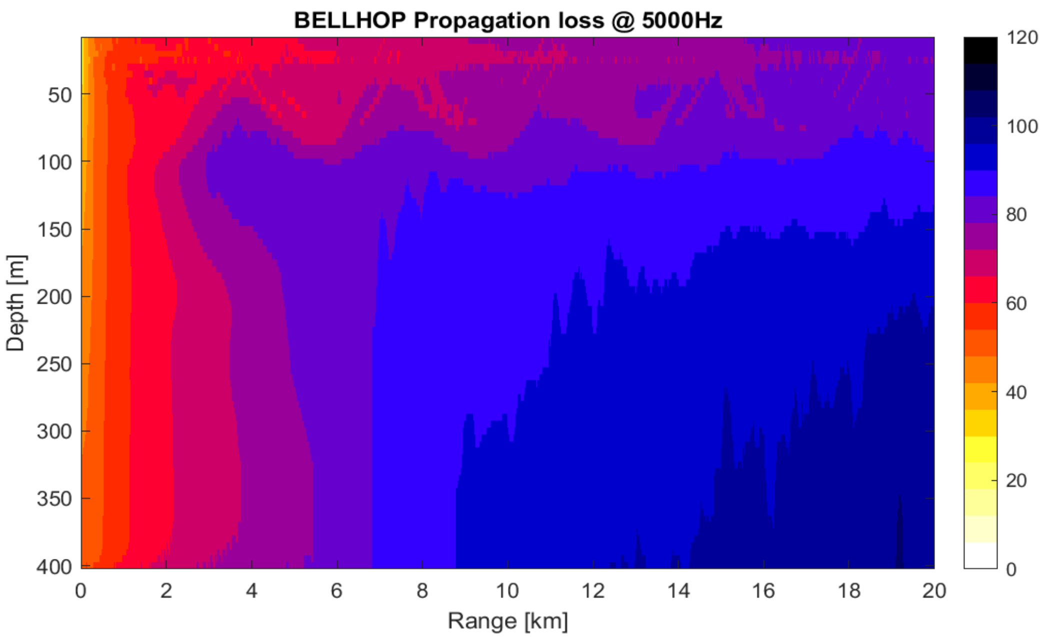
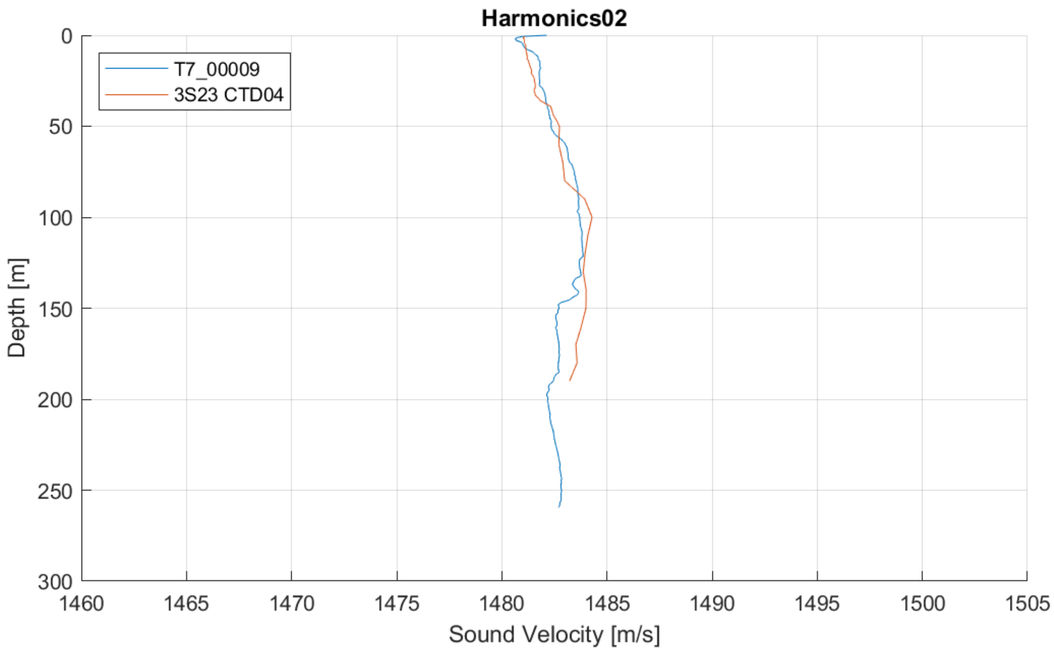


Figure 3.37 Upper panel; XBTs and CTD collected during CEE III. Lower panel: Bellhop propagation loss at 5000Hz based on the sound speed profile estimated from the measured temperature and salinity profiles.



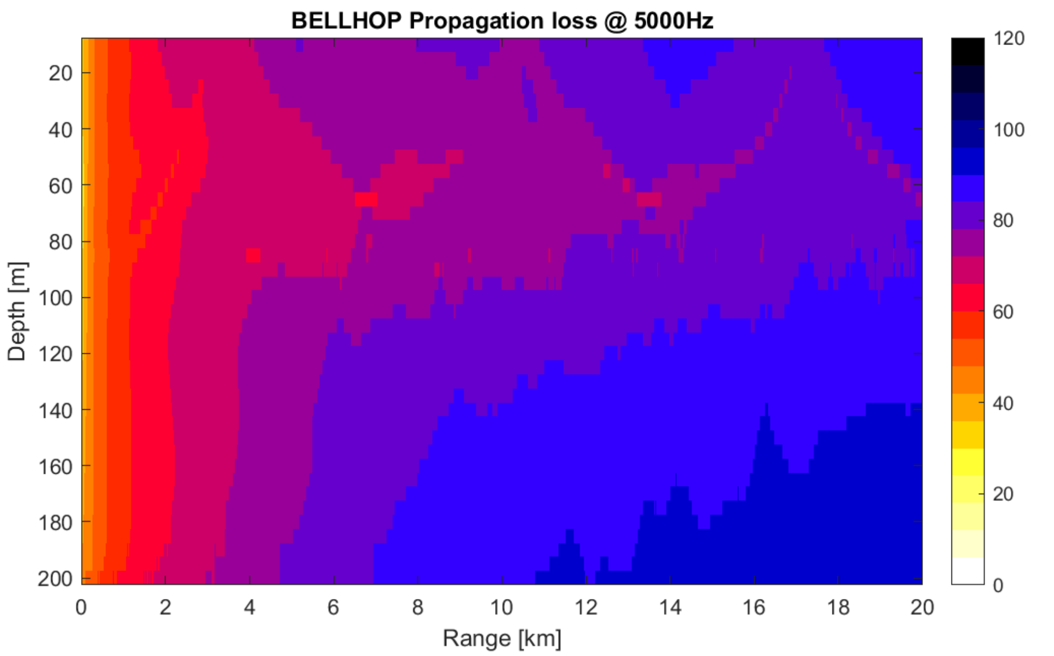


Figure 3.38 Upper panel; XBTs and CTD collected during CEE IV. Lower panel; Bellhop propagation loss at 5000Hz based on the sound speed profile estimated from the measured temperature and salinity profiles.

3.11 Photo and GoPro video data

One person on the tag boat (MOBHUS) was dedicated to taking pictures of the tagging process, tag placement and photo identification of the tagged and nearby whales using a DSLR camera. In addition, high-definition video (e.g. 4K@30fps) was recorded opportunistically, using an action video camera (GoPro) mounted with a head strap on the boat driver and/or the tagger's head. Photo documentation of 5 out of 6 SPLASH tag deployments was achieved. This was partly due to the fact that all of the SPLASH tag deployments, except two (SAT23_4 and SAT23_6), were deployed during the daytime, and that several SPLASH-tagged whales were re-encountered for later photo opportunities, often multiple times after tagging (i.e. days and weeks after). Photo documentation of mixed-DTAG deployments were difficult due to the limited light available during the predominant night-time tagging near fishing vessel effort. At night, photographs could be taken in strong floodlights, typically in close proximity to the fishing vessels. Under low-light conditions, GoPros were more effective than DSLR cameras. The auto-focus of DSLR cameras was inefficient under low light, making it difficult to capture the surfacing of a whale. Conversely, GoPros can record videos of crucial tagging moments while automatically adjusting the ISO. This feature allows us to extract snapshots of the tagging moment, which may be used for assessing tag placement and for photo identification. Examples of DSLR photos and snapshots from GoPro videos taken under different lighting conditions are shown in figures 3.39-3.41. The GoPro videos were used to evaluate the tagging process and the behavioral response of the animal to the tagging. Photo identification was used to ensure that the tagged animal was not tagged before. Photos of SPLASH -tagged animals were useful to assess how tag placement affected the acquisition of GPS Positions and relaying of data through the Argos Satellites. For future cruises, it is recommended to use DSLR cameras for tag documentation during the day and GoPro as the primary tool at night. Moreover, documentation using action cameras should be made a cruise objective, equal to photography, and not only an opportunistic effort. The quality of videos and the number of tagging events captured are likely to benefit from a planned procedure for filming, e.g. specifying video format, camera placement (i.e. fixed platform and, or head mount) and personnel filming (e.g. dedicated photographer and/or driver).

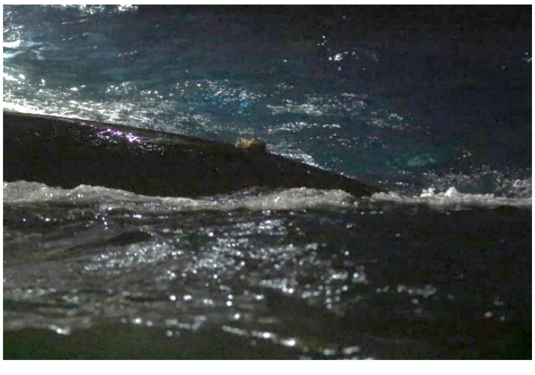


Figure 3.39 Left: Photo of a SPLASH-tag on a killer whale taken with a DSLR camera during day-time tagging (photo G. Sato), Right: Photo of a Mixed DTAG++ on a humpback whale taken with DSLR camera during night-time tagging in the floodlight of a fishing vessel (photo G. Sato).

Figure 3.40 Still image exported from GoPro video recorded from the head of the tagger during daytime tagging (photo P. Wensveen)

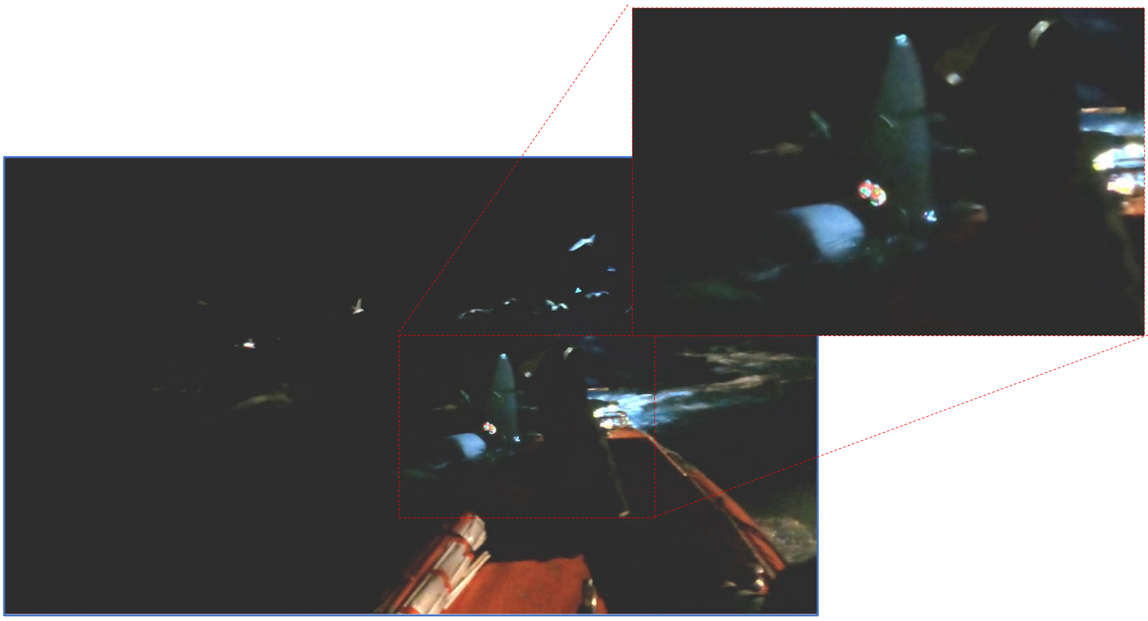


Figure 3.41 Still image exported from GoPro video recorded from the head of the tag boat driver during night-time tagging.

3.12 UAV drone data

A DJI Phantom 4 Pro unmanned aerial vehicle (UAV) was employed as a platform from which to collect photogrammetry data. UAV photogrammetry allows for high precision estimation of distances within images obtained by overflying the subject with a UAV equipped with a camera and high accuracy altimeter (Dawson et al. 2018). It can be used to estimate a variety of morphometric characteristics of individual animals.

The primary aim concerning use of UAV was to observe the size and body condition of tagged killer and humpback whales before or after sonar exposures to account for internal state mediators of responsiveness to sonar in our analysis. Due to a combination of limited daylight, unfavorable weather conditions and abundance of killer whales, which made relocating the tagged animal difficult, no flyovers were performed on tagged whales, but untagged whales were sampled opportunistically. In total, nine flights were performed over five different days (Table 3.14). Three flights were conducted for the purposes of testing, training and to obtain project footage and one was intended for photogrammetry of a humpback but was unsuccessful. The remaining 5 flights we were successful in positioning the UAV over killer whales. Flyovers were performed on untagged animals with images suitable for photogrammetry (Figure 3.42) obtained for an estimated 20 individuals.

Figure 3.42 Example of a video frame taken for morphometric measurements (photo A. Burslem). The image is taken with the camera pointing directly downwards and the animals are all well centered in the frame.

Table 3.14 Overview of AUV drone flights during 3S-2023

Date	Flight ID	Sea state (Beaufort)	Visibility	Wind (m/s)	Swell (m)	Pilot	Recorder	Objective	Target species	Estimated group size	# calves	Unique individuals with photogrammetry	Response[1]	Tagging?	Tags on
07/10/2023	280a	0	Good	1	<1	AB	GS	Testing	Na	Na	Na	Na	Na	Na	Na
07/10/2023	280b	0	Good	1	<1	GS	AB	Training	Na	Na	Na	Na	Na	y	Na
21/10/2023	294a	2	Good	4	<1	AB	GS	Photo-grammetry	Oo	7-8	Y	5	Na	Na	Na
22/10/2023	295a	2	Good	2	3	AB	GS	Photo-grammetry	Oo	15	1-2	1	0	Na	Na
22/10/2023	295b	2	Good	2	3	AB	GS	Photo-grammetry	Oo	5	1	4	0	Na	Na
24/10/2023	297a	1	Good	2	1	GS	AB	Project footage	Na	Na	Na	Na	Na	Na	Na
24/10/2023	297b	1	Good	2	1	AB	GS	Photo-grammetry	Oo	5	0	5	0	y	Na
24/10/2023	297c	1	Good	1	1	AB	GS	Photo-grammetry	Oo	5	1	5	0	y	Na
26/10/2023	299a	1	Good	4	1	AB	GS	Photo-grammetry	Mn	2	0	0	Na	Na	Na

[1] 0= No response; 1 Low response - Brief and mild, e.g. fast dive, change in speed or orientation; 2: Moderate Response – More forceful reaction but not prolonged, e.g. breach, tail slap; 3: Strong response – continued forceful reaction, multiple tail slaps/breaches/trumpet blows or sustained flight.tail slap; 3: Strong response – continued forceful reaction, multiple tail slaps/breaches/trumpet blows or sustained flight.

4 Discussion

4.1 Outcome of the trial

The 3S-2023 trial had three primary tasks (1-3) and ten (4-13) secondary tasks:

1. Tag killer whales with mixed-DTAG^{++} and expose them to dose escalating CAS or PAS twice over an extended period (8 hrs. total).

✓ *4 long duration exposures to 4 killer whales were conducted successfully. Additional attempts were made but the tag released prematurely or tracking of the tag failed.*

2. Tag humpback whales with mixed-DTAG^{++} and expose them to dose escalating CAS or PAS twice over an extended period (8hrs total).

✓ *1 long duration exposures to 1 humpback whale was conducted successfully. Additional attempts were made, but the tag released before the exposure started. The lower numbers of humpback whales exposed compared to killer whales reflects the priority to tag and expose killer whales.*

3. Tag killer whales with SPLASH10-F-333B tags in the core operation area (higher priority early in the trial).

✓ *6 killer whales tagged with Splash Limpet tag during the first two weeks of the trial.*

4. Tag killer whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible).

○ *This task was not done because it was a back-up plan in case long duration exposures was not feasible. This back up plan was not needed.*

5. Tag humpback whales with mixed-DTAG^{++} and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible)

○ *Same as task 4. Not done because it was a back-up plan, and the back-up was not needed.*

6. Collect echosounder data to monitor the prey field.

✓ *It was not feasible to calibrate the echosounder, but uncalibrated data were collected continuously in search and experimental phases.*

7. Collect 24 h duration baseline data records of target species.

- ✓ *The 6 Splash tags collected data on diurnal patterns of killer whales over periods from 1 to 7 weeks. In addition,* mixed-DTAG++ *collected 98 hrs. of baseline data, of which 5 records were over extended periods of 11-28hrs.*

8. Collect drone footage of tagged subjects for body condition characterization.

- ✓ *Due to a combination of limited daylight, unfavorable weather conditions and abundance of killer whales, which made relocating the tagged animal difficult, no flyovers were performed on tagged whales but untagged whales were sampled opportunistically.*

9. Collect information about the environment in the study area (CTD, XBT)

- ✓ *8 XBTs and 4 CTDs were collected in the area where the exposure experiments were conducted.*

10. Collect acoustic data using a towed array.

- ✓ *The Delphinus system was only deployed on three occasions during the first 2 weeks when we were not working around fishing vessels. A few whale detections were made, but it got complicated to maneuver in shallow in-shore waters, and therefore the array was quickly recovered.*

11. Collect sightings of marine mammals in the study area.

- ✓ *407 visual sightings of seven cetacean species were made during the trial.*

12. Perform sound source long duration engineering test and harmonic characterization.

- ✓ *Harmonics characterization and extensive endurance tests were made for both the LFAS source and MFAS source of SOCRATES.*

13. Collect herring samples around feeding whales.

- ✓ *30 herring were collected and preserved for future analysis of energy content.*

All things considered the 3S-2023 trial must be considered a great success. However, we were hoping to collect more data on long- and short duration exposures to CAS and PAS. Such experiments have never been conducted before, and in order for us to pull it off we needed the new technology of direct whale-ship GPS tracking to be working well at relatively long ranges. As it turns out this system worked very well but can also be improved.

4.2 Issues and concerns

During the trial we experienced unexpected serious issues that affected data collection rate or data quality:

The herring purse seine fishing fleet arrived late on the fishing grounds and when they did arrive, they mostly worked 150-200nmi off-shore, most likely because that is where the herring shoals were most dense.

In this period, we had unusually bad weather offshore and therefore could not operate around the fishing vessels to tag whales as intended. This affected tagging efficiency and our ability to work on the primary tasks. Luckily the weather improved during the second half of the trial, and the fishing fleet also moved closer to the coast. In this phase the problem was that the fishing fleet was very aggregated, and we therefore ended up doing all the CEEs in the same area. This is not desired. To mitigate this issue for next year's trial we will consider starting later and increase tagging efficiency by use of the ARTS and having more tags available. However, we have some concern about availability and reliability of DTAG core units.

We also had a serious issue with failure of the LFAS transducer of the SOCRATES source. We ended up switching source from the LFAS transmitting 1-2kHz @ 214 dB ESL_{20s} re 1 $\mu Pa^2 \cdot s \cdot m^2$ to the MFAS transmitting 4-6 kHz @ 197 dB ESL_{20s}. This is not optimal because the source level of the MFAS source is significantly lower than those of naval operational systems. Killer whales have more sensitive hearing in the MFAS frequency band, which might compensate for the lower source level, but humpback whale hearing is likely less sensitive in the MFAS frequency band. During the trial a lot of effort had to be spent testing both the LFAS source and the alternative MFAS source. At present we have serious concerns about availability of a proper CAS source for 2024.

4.3 Hot wash de-brief recommendations

At the end of the trial, we did a hot wash de-brief with the science team on HU Sverdrup. The aim was to summarize the achievements and events of the trial and brainstorm around possible improvements for the next trial based on this years' experience. We compiled a list which will be considered during planning of the next 3S-trial in 2024, which is planned to have a very similar objectives and tasks as the 3S-2023 trial. The list comprises suggestions over the table from someone within the group and does not mean that there is consensus within the group about it. The list could also be considered a 'wish list', and before implementation, cost benefit and cost coverage will have to be considered by the 3S-board.

Experimental design

- Consider starting 2 weeks later next year and try to avoid crew changes.
- Consider baseline duration of CEEs. The context between nighttime feeding during baseline and daytime resting during exposure is so different in many of the experiments.
- Consider the need for more baseline data (dedicated baseline trial).
- Expand the second tagging window when the 48 hr rule delays the exposure.
- Mix up exposure times, some at night, some during daylight.
- More guidance on turning after CPA.
- Evaluate to use satellite tagged whales as focal animals in CEEs (this year they were all non-focals) – this would enable exposures in different contexts and repeated exposures on the same individual. This would require direct GPS reception from the tag to conduct the CEE.
- Use non-GPS data as well as possible during GPS-data gaps (Argos fixes, visual sightings, VHF-receptions)

- Consider shortening the exposure period when there is only 1 focal whale.
- Assure smooth communication across shifts within each sub-team.
- Consider more rehearsal ‘exposure-sessions’ to practice full routine.

Tags, tagging, tag boats

- Do we need the Splash satellite tags, how useful were they? Maybe we need more if we work offshore? Ideally deploy them before the CEE trial on a separate effort. Consider modifying tag settings based on experience from this year.
- We need more mixed-DTAGs. Ideally 8 fully functional systems to not be limiting and to enable more tagging effort.
- Quantify tags deployed per unit effort from 2023 trial.
- Search torches on MOBHUS and headlights for tag teams. Better lighting systems – modify front light? Install new lights?
- Enable AIS reception on MOBHUS.
- Install swivel-seat for MOBHUS driver.
- Use of the ARTS - we need to be able to tag free-ranging animals so that we can switch area more. Need to evaluate tag placement outcomes, compare to hand-pole outcomes (could be done during pilot study). Would require trained ARTS taggers.
- Have 2 taggers on one tagging boat, one DTAG one SAT-tag tagger, or one pole one ARTS tagger.
- TNO RHIB can only be deployed and recovered safely in flat calm weather in/shore. It can also not be hanging in the ships crane over time because the stress on the crane. With these limitations the operational benefit might be pretty close to 0. Might be usable in-fjord, if there are fishing vessels present there. Working in-shore could potentially increase whale watching conflict.
- Install a second MOB crane on Sverdup to enable 2 tags boats at sea.
- Consider communication plan if 2 tag boats, enables double effort, redundancy in case of boat problems.
- Combine (rotate) roles of MMOs and tag-boat teams. More taggers, boat drivers, tag technicians.
- Use solid state external hard drives for faster copying.
- Continually improve remote prediction of good tagging opportunities at fishing boats (AIS, details of vessels e.g., lights, broken nets, structured communications with vessels, time of day etc.).
- Tag status board was useful, keep using it and keep it up to date.

Sonar Source and acoustic array

- We need a CAS source with realistic source levels, and preferably at lower frequencies.
- Explore if such a source could be the TNO source SOCRATES II or the Dutch Navy source SOCRATES III
- Consider access to operational navy Frigate with CAS
- Explore availability of other sources (e.g., a towable flextensional sources, CMRE sources, Ultra sources available through DSTL.

- Cruise plan needs to include all details of all transmissions, including ramp up.
- Delphinus was not much used during the trial. SAT tag replaced function.
- Towable acoustic array might become more useful in different situations.

CEE tool and tracking

- The CEE tool and direct whale-ship GPS tracking worked great!
- Add different sounds for each tag to indicate position update.
- The CEE-tool responds very slowly. Bathymetry map is so inaccurate that it can't be trusted for navigation anyway. We might as well get rid of the background map with low resolution bathymetry if that helps speed up updates.
- If it helps, remove GPS error ellipses to speed up.
- Get a faster computer.
- AIS was very useful in the tool, because we don't have that in NavyPac/Planning
- Consider if we can implement quantitative extrapolation of whale movements to better predict CPA.
- Add status updates on error messages when GPS is not received.
- Add warning sound indicators when GONIOMETER is down (e.g., lost USB mode).
- Change 24hr time filter to a flexible slider
- Add ARGOS quality filter.
- Improve range of DFHorten Box. Might require change of VHF transmitter in the tags.
- Get a spare Goniometer antenna system in case of failure.
- Save realteime.exe terminal output.
- Add tag status (available, prepared, deployed, etc.) to CEE tool.

MMO and mitigation

- Evaluate MMO staff requirement for next year, needs to enable 8hr mitigation with appropriate rest periods for effective mitigation observations.
- Number of emergency shut-downs demonstrates importance of mitigation
- More advance training on the Pulse Mergers use and settings, how to estimate range.
- Clearer radio communication protocols
- Keep using two staff on bridge during key parts of exposure period.
- Mobile radio on the bridge would aid communication.
- Limit VHF radio communication (jams VHF-tracking), use strict communication protocols. Reconsider walkie-talkies during mitigation.
- Enable direct shut down from MMOs to Socrates – this might not be desired.
- Consider options to not use radar at night, if observers report relevant observations for navigation.
- Consider use of deck space outside front of bridge
- Have clearer weather criteria on moving mitigation team from observation deck to bridge deck.
- Consider automatic 360-degree observation system for mitigation to replace observers.

Prey field mapping

- Seem to work ok – value of un-calibrated data is unclear.
- Consider using the multi-beam echosounder system on Sverdrup.
- Approach IMR for herring prey-mapping data
- Consistently stay 1-2 km from focal during baseline and post-exposure
- Fish data collection should record location and time of collection.
- Specify number of fish to collect.
- Look at catch reports from fishing boat for catch and fish sizes.
- Relate tag deployments to specific fishing boats.
- Physical datasheet for collected fish.

Safety

- Medical seafarer certificate and safety training will probably be a hard requirement next year. Check validity duration of certificates.
- Everybody should bring personal safety equipment (protective shoes, suites are assumed to be personal, bring your own). Helmets can be provided by Sverdrup.
- Very positive feedback from safety officer on our training of risky operations (tag boat deployment and recovery).
- Safety incident during SINUS RHIB deployment could have resulted in injury to people and equipment. Procedures need to be even more safe.
- Assure reliable and correct use of batteries on MOBHUS.
- Consider installing AIS reception on MOBHUS.
- Ship's crew was very skilled to assist during our operations.
- Having some speed by Sverdrup during recovery of tag boat is more stable.
- Have clear communication for MMOs to avoid unsafe conditions on observation deck.

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Appendix

A 3S-2023 Data inventory

The following data was recorded/created during the 3S-2023 cruise. This data has been shared between all partners.

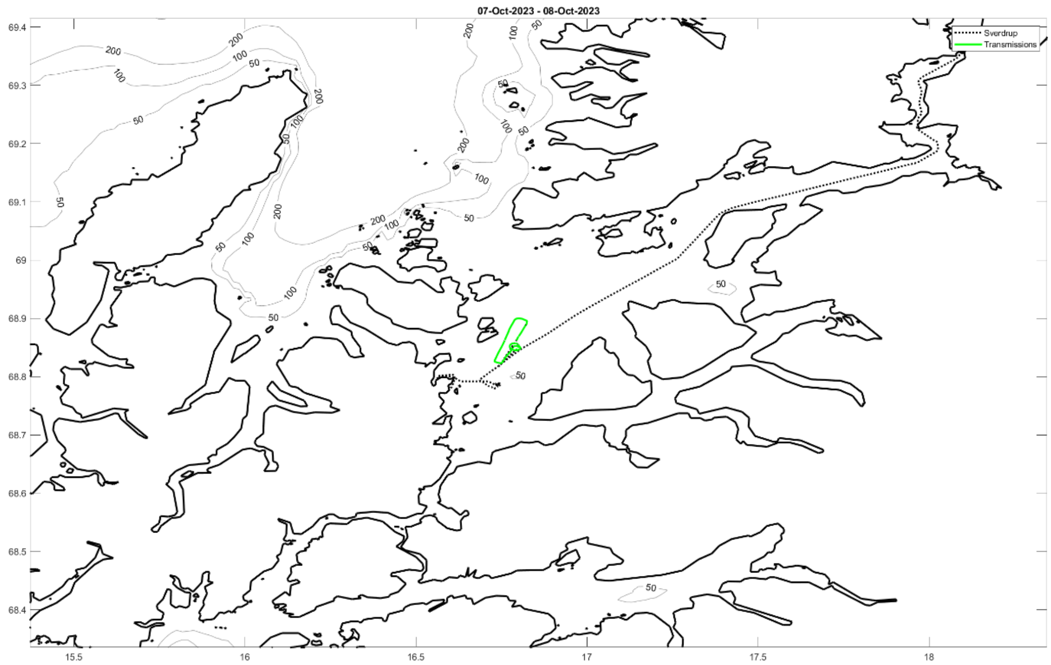
Folder	Description
acousticDataAndResults	Analysis scripts to verify if the rampup and subsequent pulses were audible in the recorded audio data of a tag. The script uses a matched filter analysis on specific wav files.
Bridge log	Logbook of the bridge, including daily orders published to the crew.
Briefs	Presentations of the crew briefing and closing hotwash meeting.
CEE Tool	Images, movies and screenshots made using the CEE tool. This folder also contains the CEE tool databases, sorted per experiment.
CTD_XBT	Recorded CTD and XBT data during the trial.
Drone data	Drone recordings.
DTAG	All DTAG associated data
echosounderData	Data recorder by the H.U. Sverdrup II echosounder.
fishSample	Fish sample logs
Goniometer data	Recorded data of the goniometer bearing and GPS positions of the tags.
GPSlogs	GPS and AIS logs of H.U. Sverdrup II
Logger	Logger logs, containing sightings and relevant events.
ObsDeck	Useful info printed for obs deck about tags.
Pics and videos	Pictures and videos.
Satellite tags	Argos satellite data configuration.
SocratesLogs	GPS and transmission logs of the Socrates source.
Software	Some useful software tools.
TrialOverviewPictures	Day to day images of the Sverdrup track and sonar transmissions.

Note that the data was distributed using a software tool “Sync Toy”. The data was transferred from a laptop to several USB connected drives. Due to a lack of USB ports, and insufficient disk space on some drives, drives needed to be swapped and custom data selections needed to be made. Especially swapping drives (and therefor drive letters) was an issue for SyncToy, which did not always fully synchronize data. This problem was only discovered near the end of the trial.

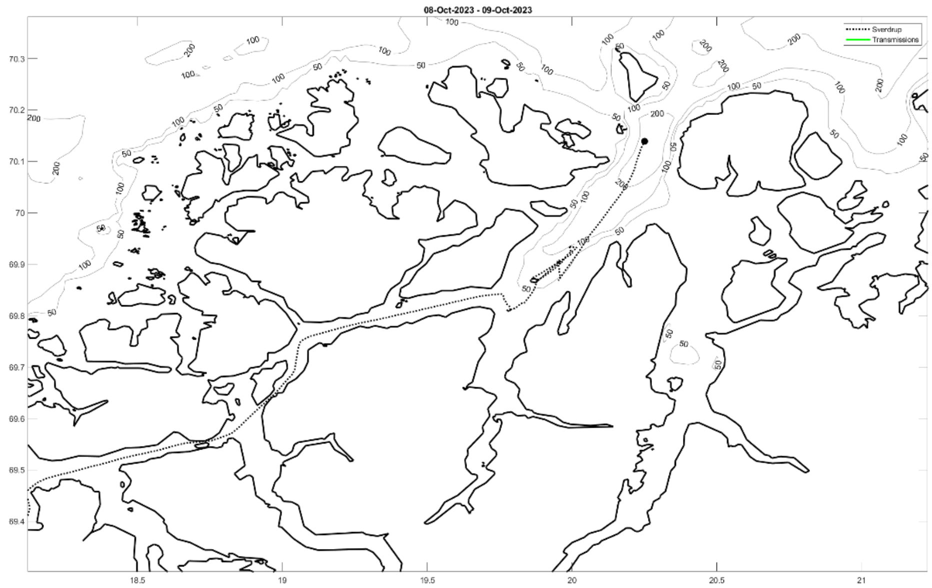
For the next trial, it is recommended to have a dedicated backup facility, equipped with enough USB ports to connect drives of all partners. Partners should also bring a fast USB drive (>100 MB/s write speed) with a capacity of at least 4 TB. This will allow SyncToy to function correctly, without too much manual interference.

B 3S-2023 Daily activity and sail tracks

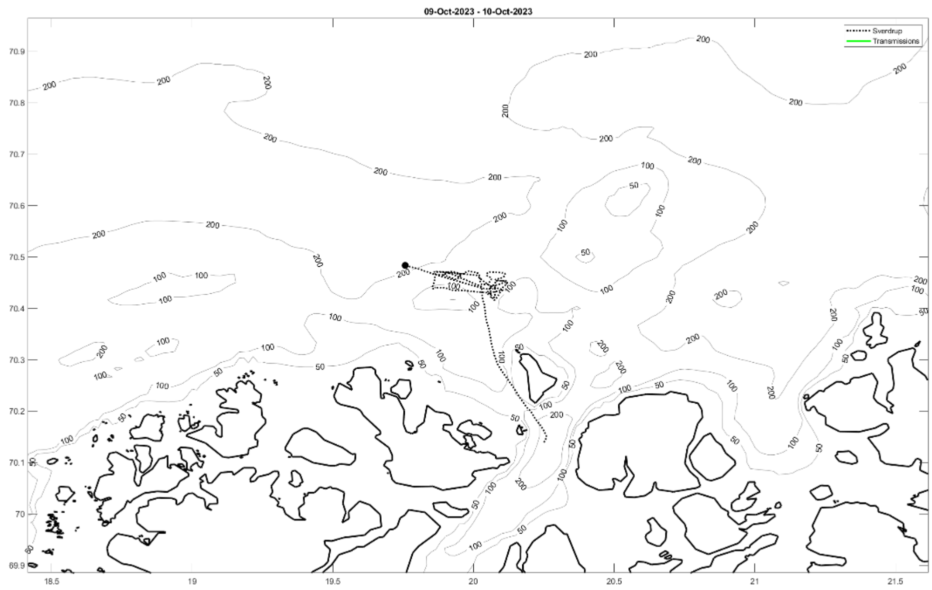
Figure B.1 Overview of sailed tracks for every day of the 3S-2023 cruise. The black dotted line indicates the sailed track of the H.U. Sverdrup II, where the black dot at the end of the line indicates the position of the Sverdrup at the end of the day. The green line indicates parts of the track where the sonar was active. Plots run from the date on the left starting at 00:00 UTC, and end at 00:00 of the right date. KW is killer whales and HW is humpback whales. Missing days were spent in port in Harstad during mobilization (Oct. 5th-6th), or transit and demobilization (Oct 31st – Nov 2nd).



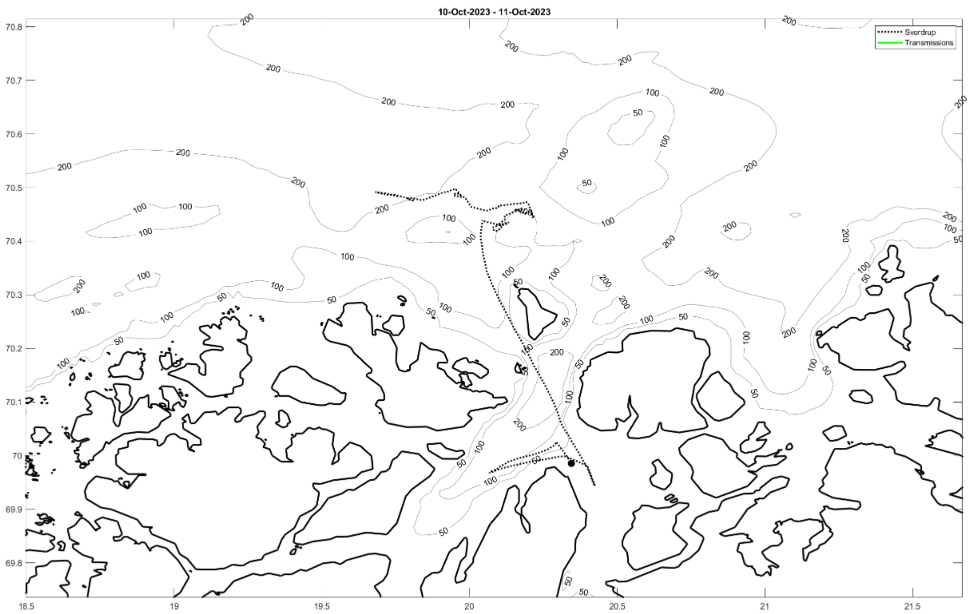
Oct 7 - Safety training with tag boats, harmonics and endurance test of Socrates in Vågsfjord. Overnight transit.



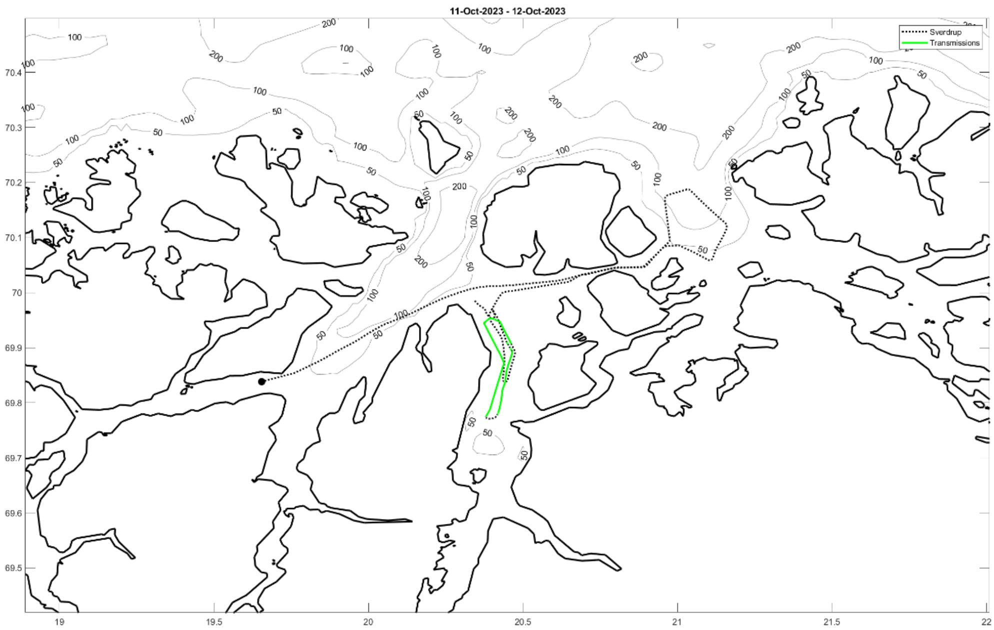
Oct 8 - Working to fix Socrates. Tagging and MMO training in Ulsfjorden. VHF and Goniometer range and bearing tests of tags in Lenangen.



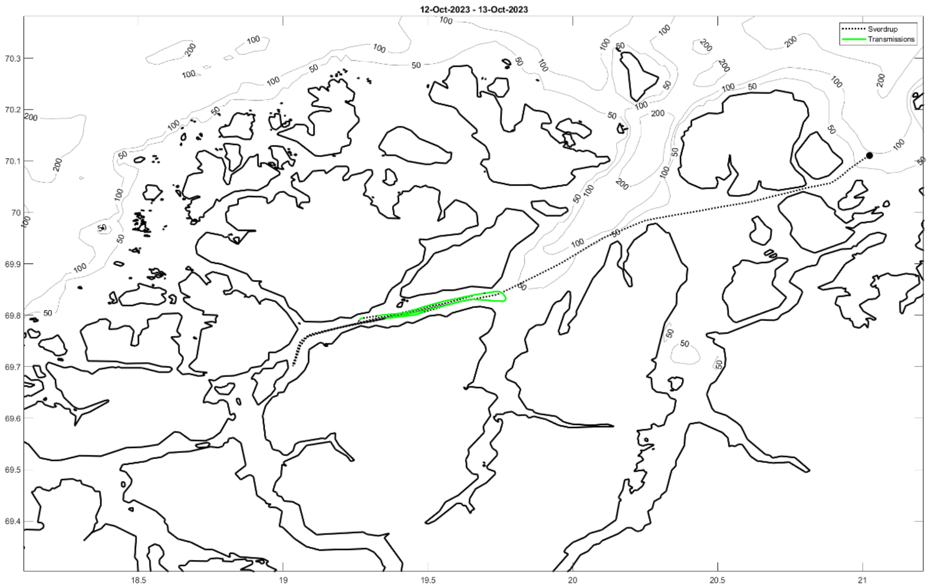
Oct 9 - Tagging KW and HW at Fugløybanken. Tagged a big male kw with a splash tag.



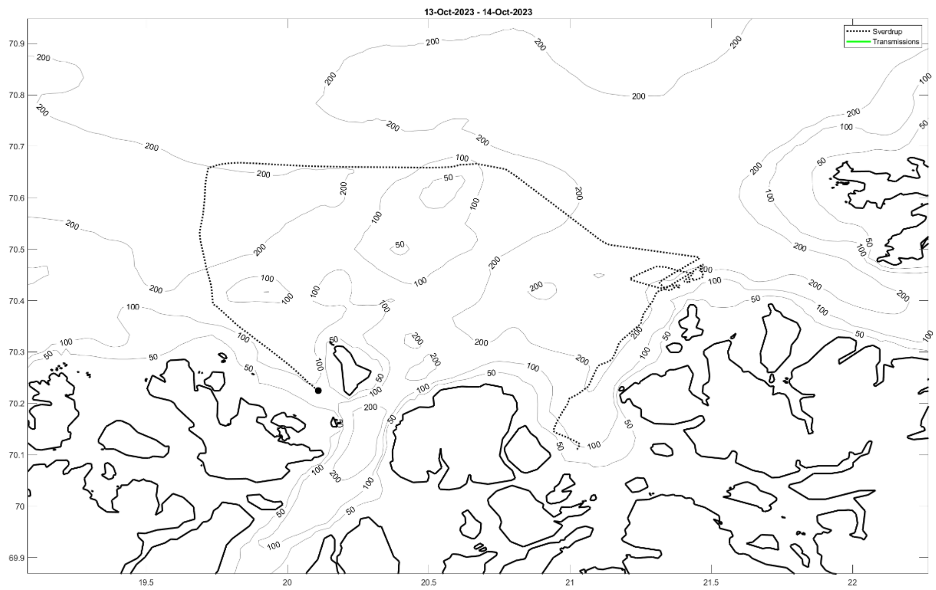
Oct 10 - Tagging KW and HW at Fugløybanken. Tagged a big male kw with a splash tag.



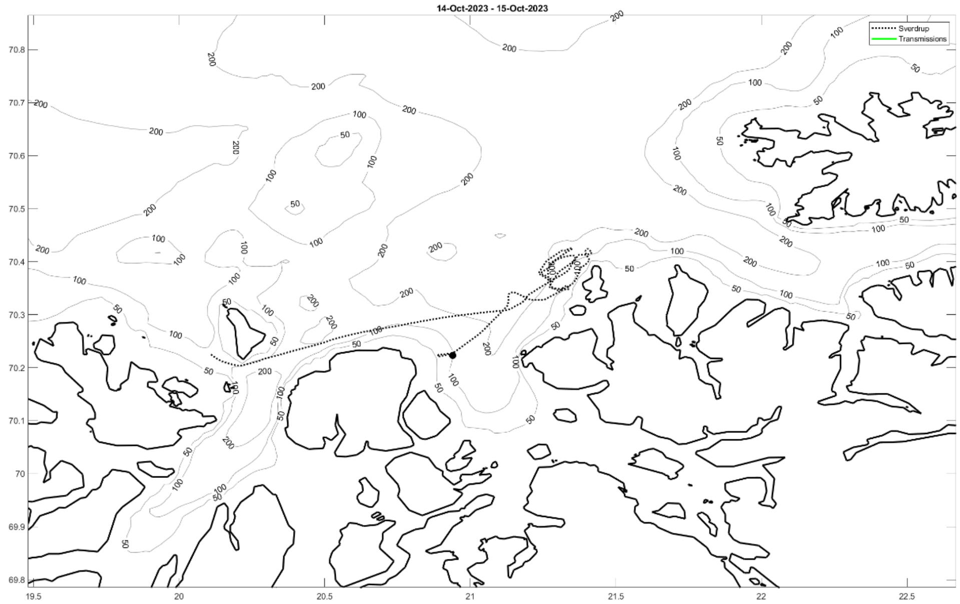
Oct 11 - Testing the MFAS source of the SOCRATES II with 4-6kHz CAS and PAS in Lyngen. Visual and acoustic survey in Kvænangen - no whales.



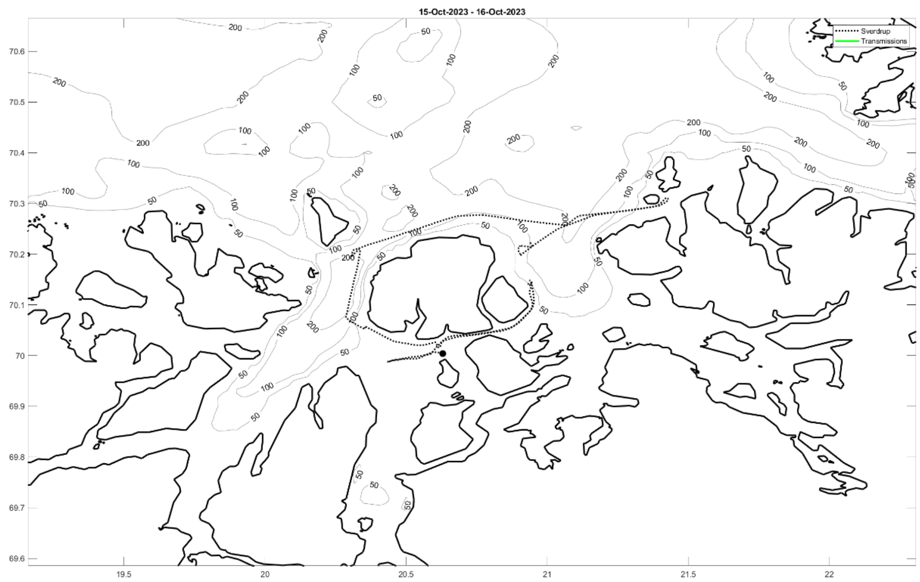
Oct 12 - Dropped of MOBHUS for repair in Tromsø. Testing MFAS source in Grøtsundet.



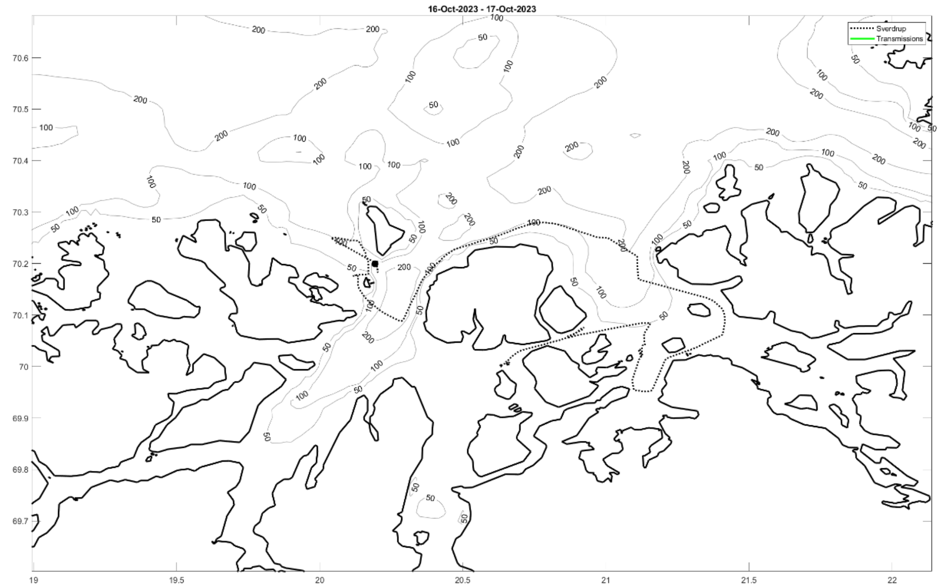
Oct 13 - Working with KW and HW at Lopphavet. Deployed another splash tag to a male KW.



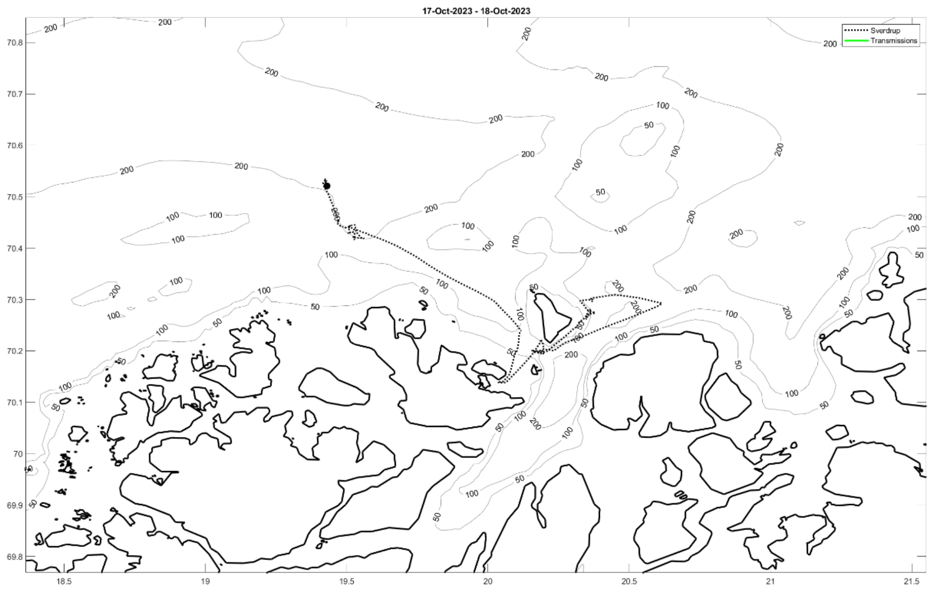
Oct 14 - Working to tag with mixed-DTAG++ at Lopphavet. Many whales, but no success.



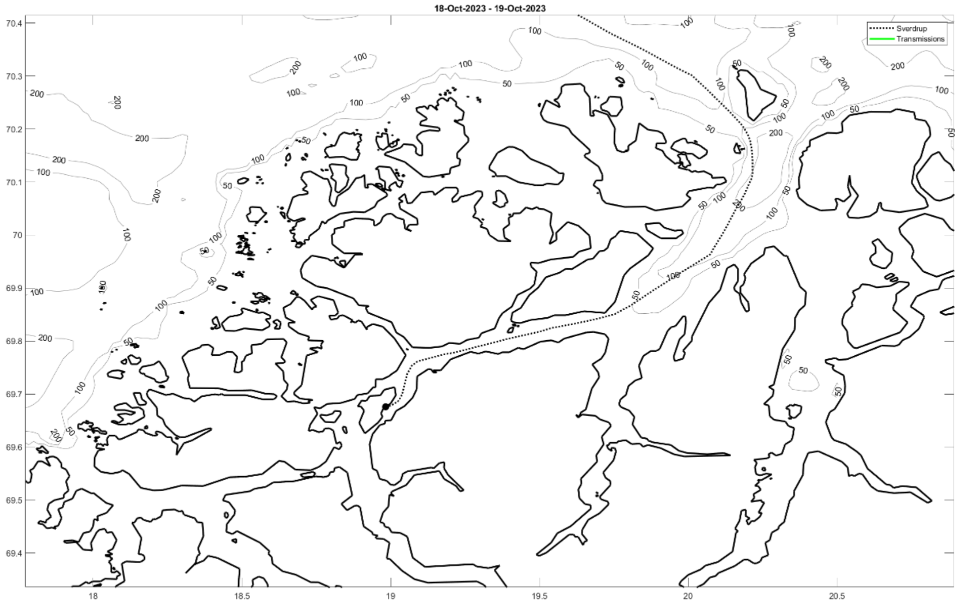
Oct 15 - Searching for whales in-shore in Kvænangen.



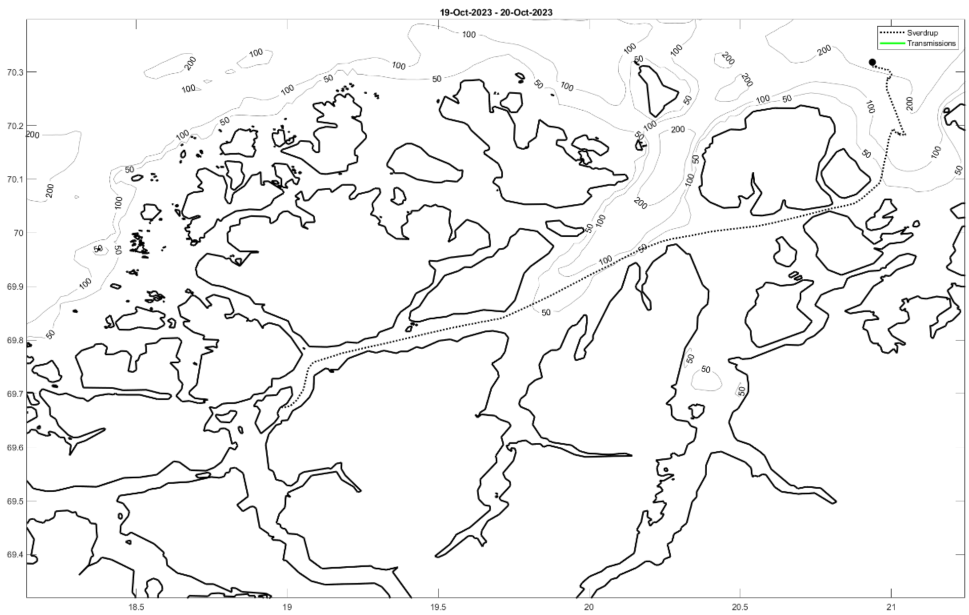
Oct 16 - Searching for whales in-shore in Kvænangen. Weather too rough offshore.



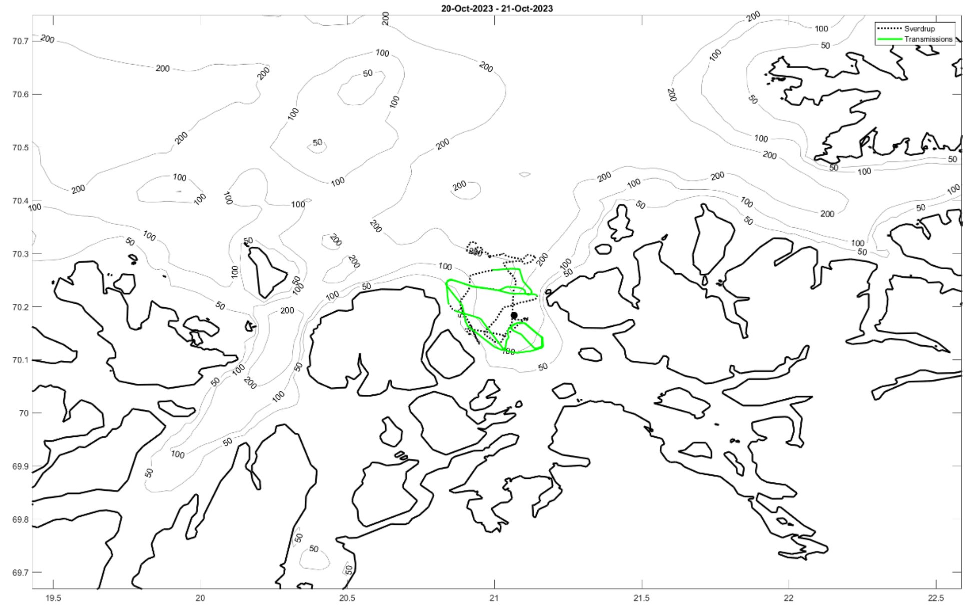
Oct 17 - Deployed three Splash tags to KW and tagged two KWs with mixed-DTAG^{++} *around fishing vessels at Fugløybanken. Both tags came off before any exposure was conducted.*



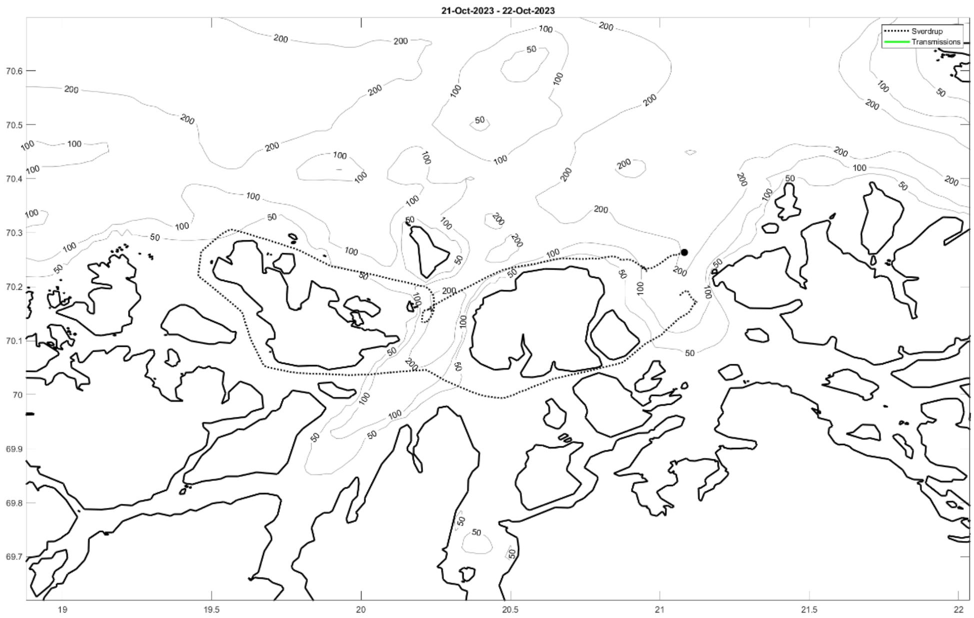
Oct 18 - Transit to Tromsø for crew change and replacement of Socrates II with Socrates III



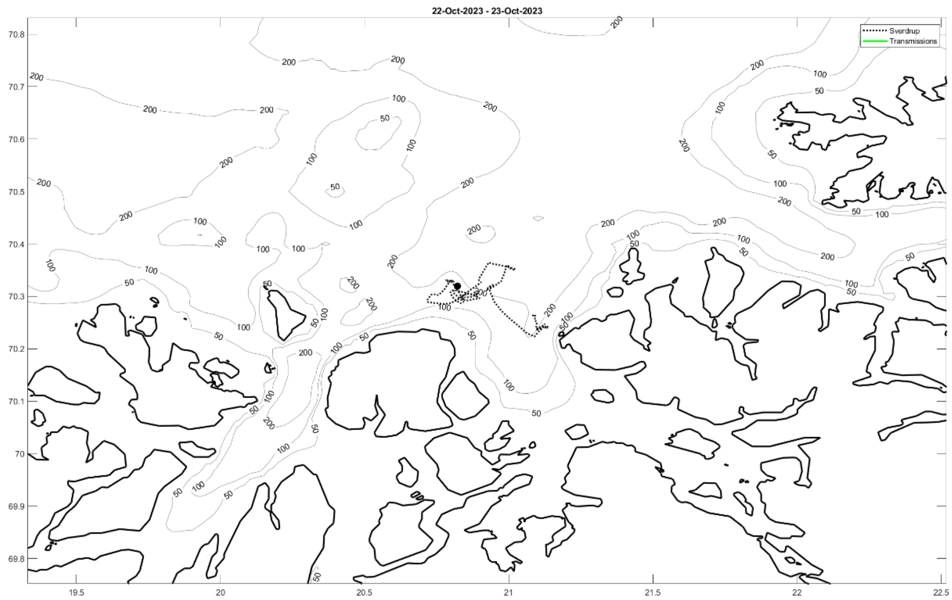
Oct 19 - Transit back to Lopphavet through Kvænangen, tagging killer whales around fishing fleet.



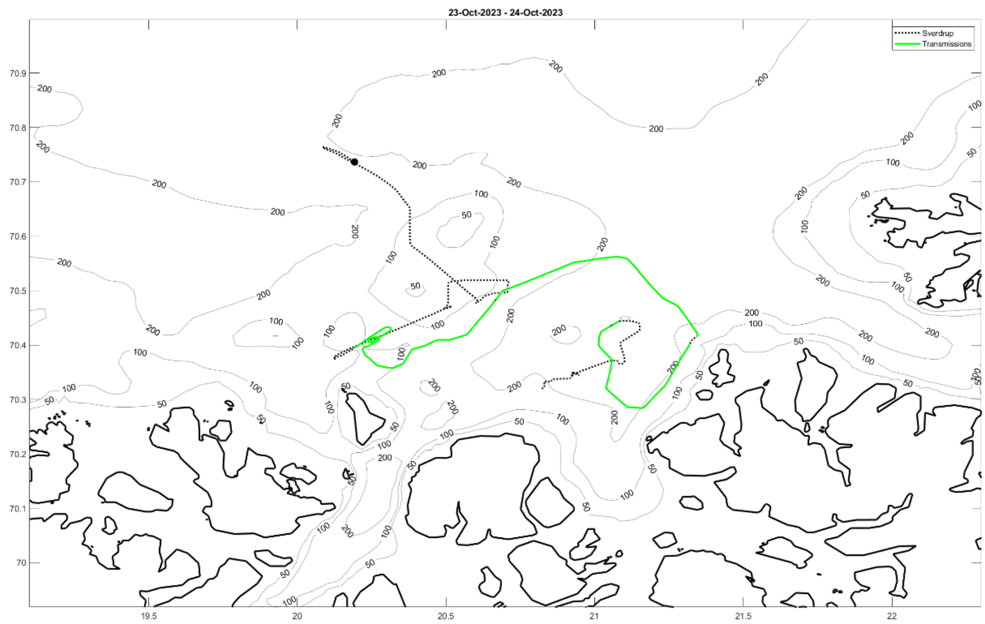
Oct 20 - Two mixed-dtags deployed (KW, HW) in Kvænangen. Conducted CEE I (MFAS CAS)



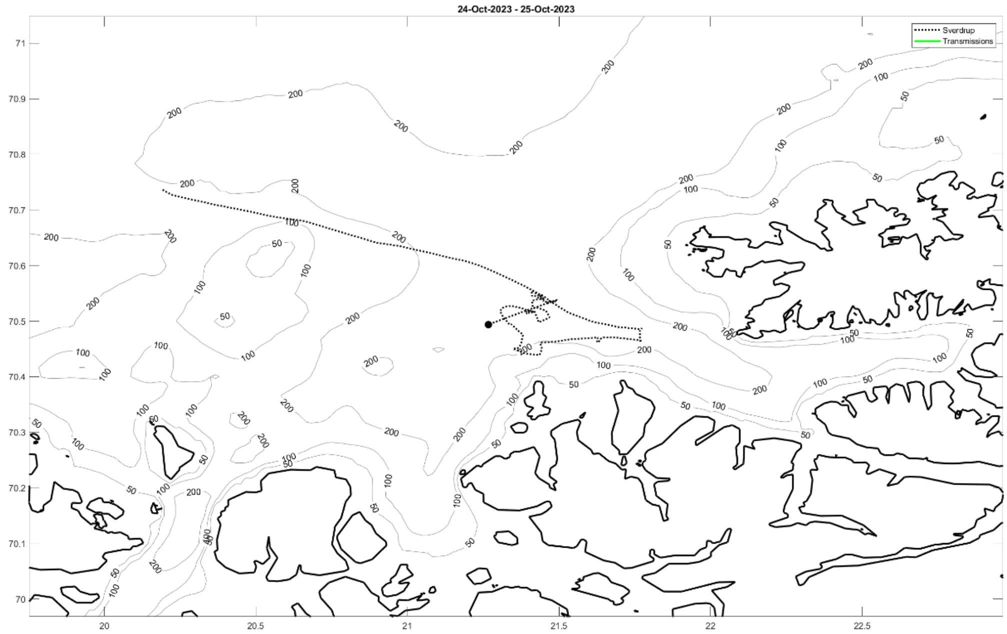
Oct 21 - Searching for and tagging whales in in-shore waters during daylight and around fishing boats at night.



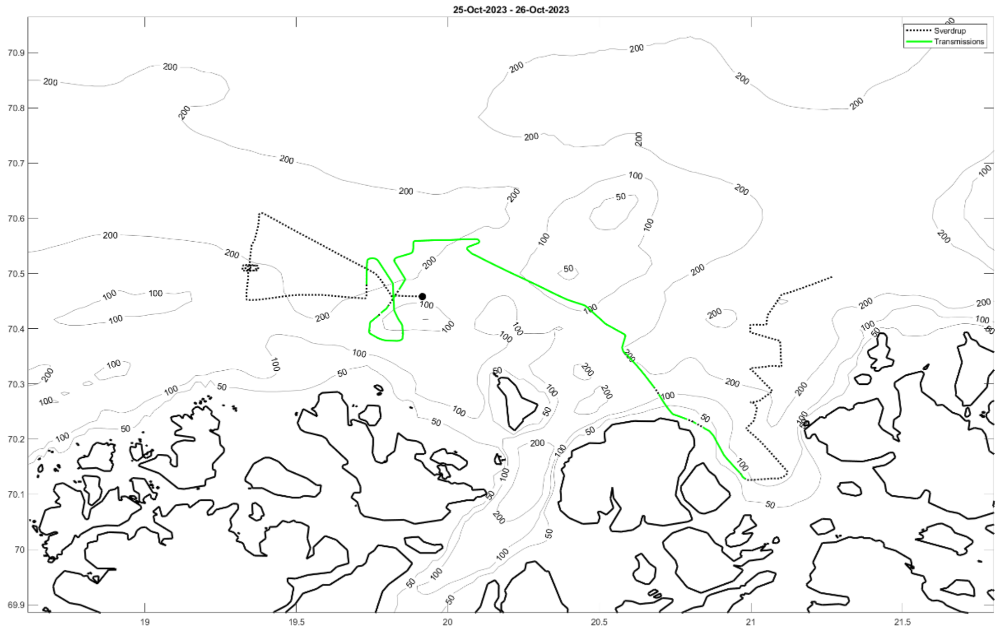
Oct 22 - Tagging around fishing fleet, tagged a big male and a female KW with mixed-DTAG++



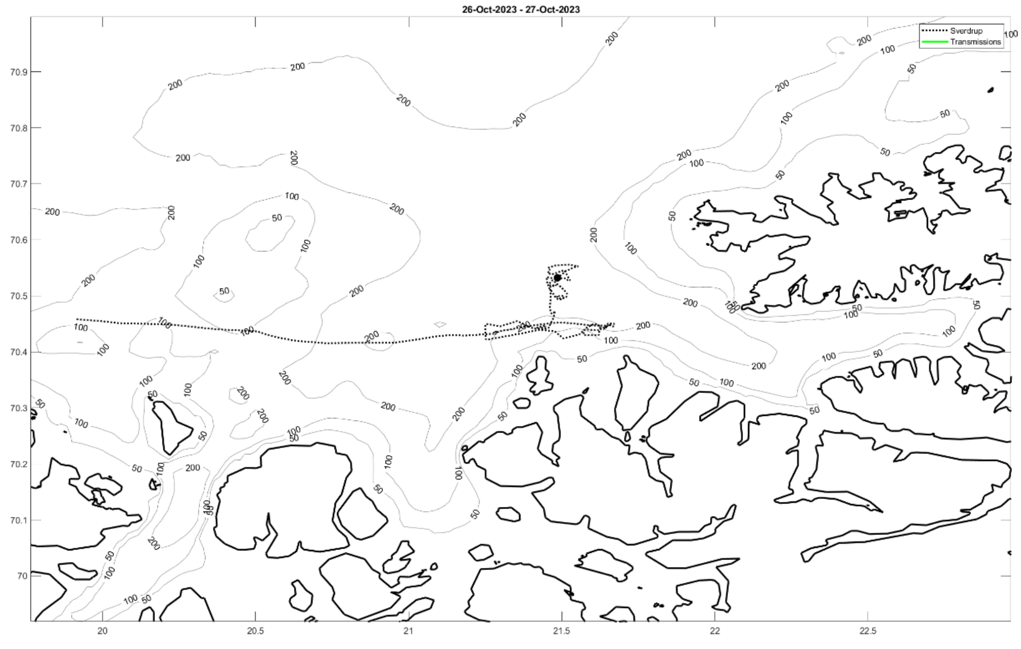
Oct 23 – Conducted CEE II (MFAS PAS) at Lopphavet, transit north to new area



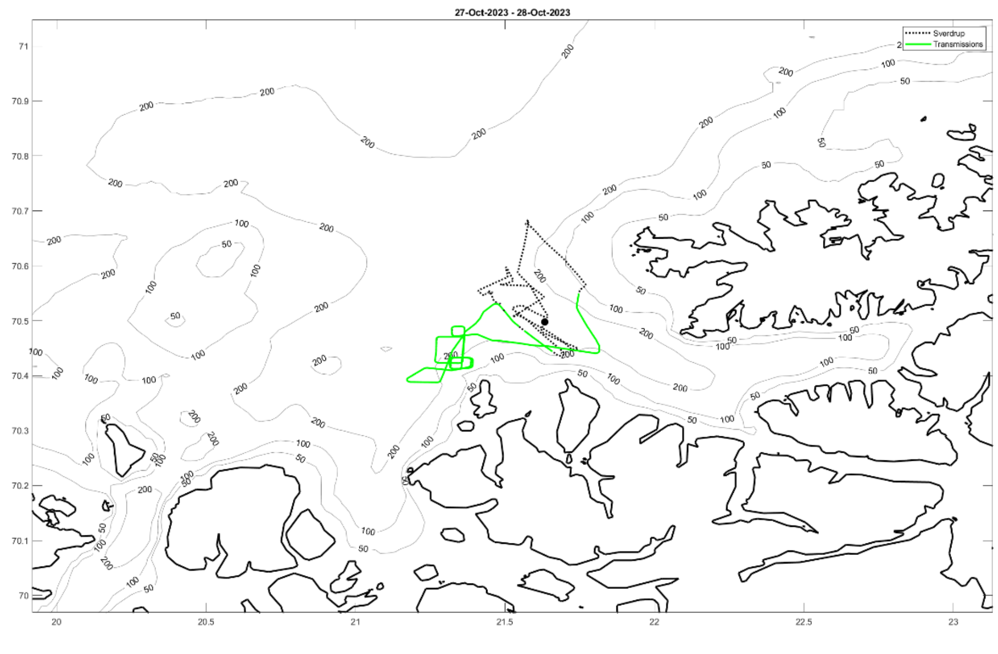
Oct 24 - Tagging KW free swimming and around fishing vessels at Sørøysundet. 2 mixed-DTAGs deployed. Conducted CEE III (MFAS CAS)



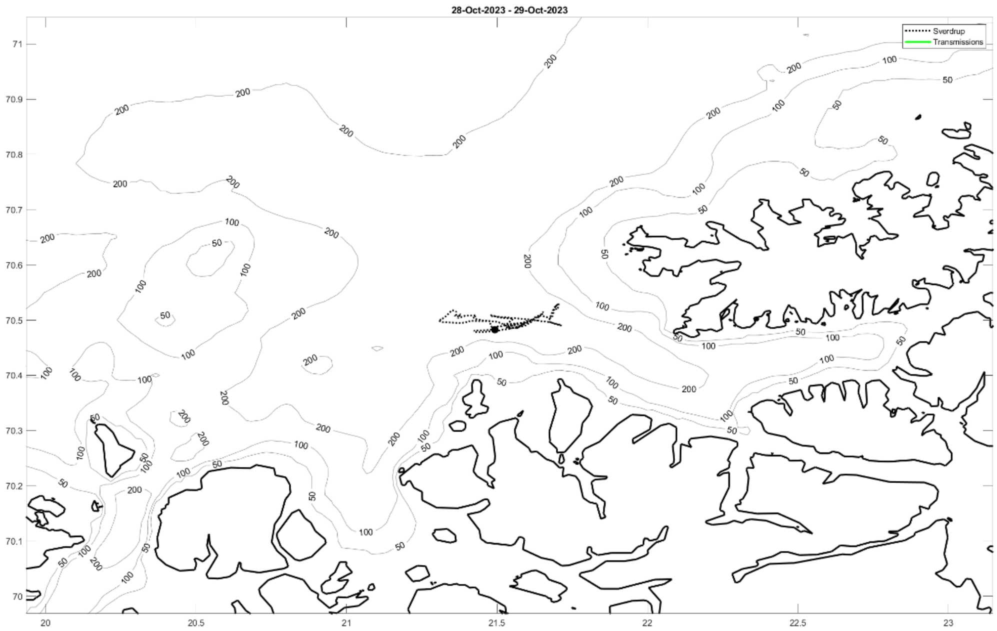
Oct 25 – Finished CEE III, transited to new and area started tagging again at Lopphavet



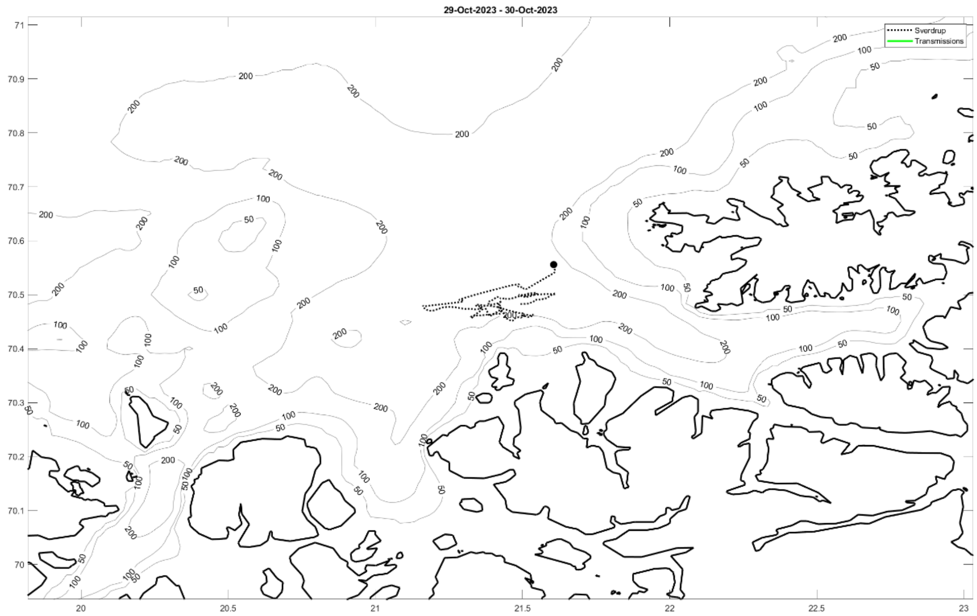
Oct 26 - Tagged a HW for baseline, and 2 KWs for CEE at Lopphavet.



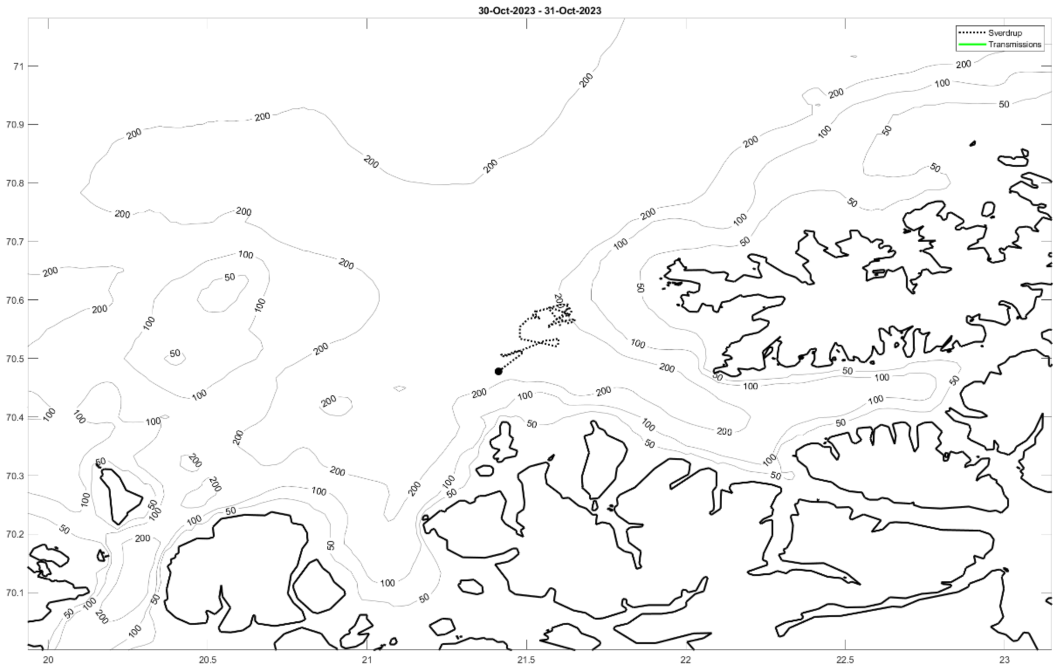
Oct 27 – Conducted CEE IV (MFAS PAS) at Lopphavet.



Oct 28 - Tagging around fishing vessels in Sørøysundet, two tags deployed (KW, HW) for baseline records.



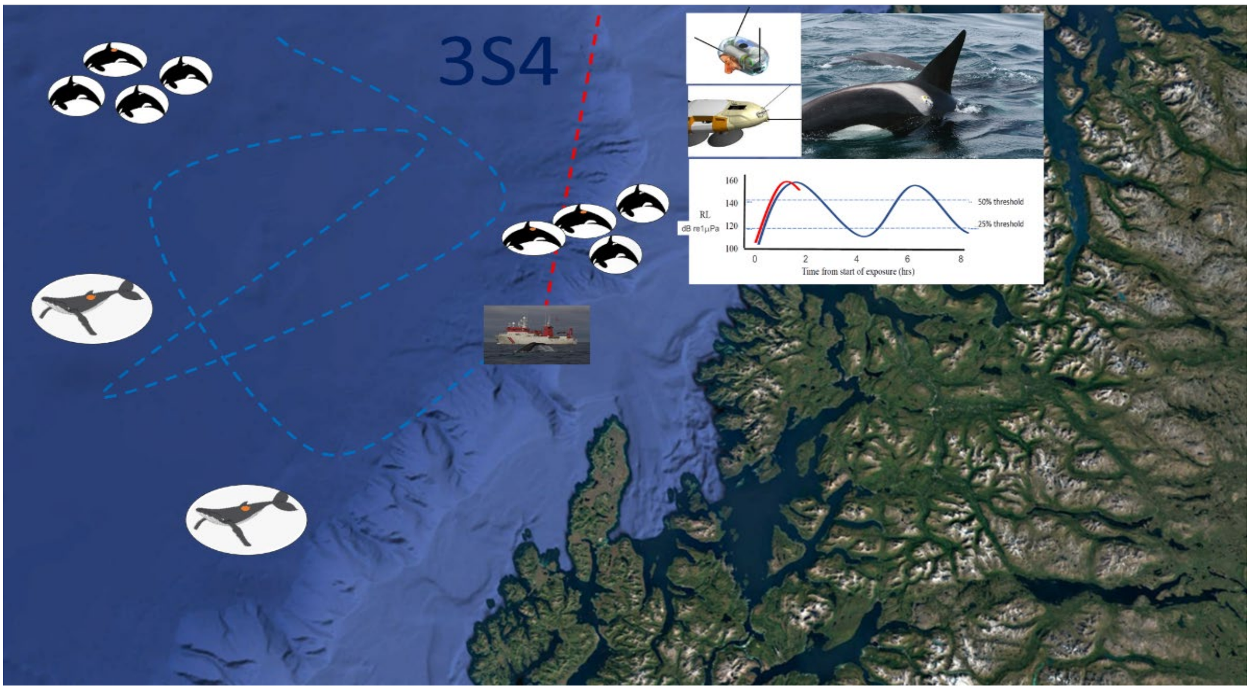
Oct 29 - Tagging around fishing vessels in Sørøysundet, two tags deployed (HW, KW) for baseline record



Oct 30 – Tagging in Sørøysundet, 1 tag deployed for baseline (KW). MFAS harmonics test before transit towards Harstad

C 3S-2023 Cruise plan

3S-2023
Cruise Plan



FINAL VERSION

The 3S-2023 research trial is conducted by the 3S-consortium as part of the 3S4-project.

CONTENT

LIST OF ABBREVIATIONS

3S	Sea mammals and Sonar Safety project
3S4	Fourth phase of the 3S project 2023-2026
AORI	The Atmosphere and Ocean Research Institute at the University of Tokyo
ARTS	Aerial Rocket Tagging System for remote deployment of whale tags
BRS	Behavioral Response Study
CAS	Continuous Active Sonar
CEE	Controlled Exposure Experiment / CEE Exposure coordinator
CO	Commanding Officer
COMMIT	Materiel and IT Command (formerly DMO)
CPA	Closest point of approach
CTD	Conductivity-Temperature-Depth, sensor to measure density/sound speed profile
Delphinus	TNO towed array system for acoustic detection and tracking of marine mammals
DGA	The Direction générale de l'armement, part of the French Ministry of Defence
DM	Data management
DMO	NL Defence Materiel Organization (now COMMIT), part of NL Ministry of Defence
DP	Drone Pilot
DRDC	Defence Research and Development Canada
DTAG	DTag, as originally developed by WHOI. Currently provided by Univ of Michigan
FFI	Forsvarets forskningsinstiutt / Norwegian Defence Research Establishment
GPT	General Purpose Transceiver, contains the transmission and reception circuitry for echosounders
HF-Cetacean	High Frequency cetacean hearing specialist (killer-, pilot-, sperm whales and dolphins)
HFM	Hyperbolic Frequency Modulation (type of sonar signal/sweep)
HUS	R/V H.U. Sverdrup II, research vessel of FFI
HW	Humpback Whales
KW	Killer Whales
LF-Cetaceans	Low frequency cetacean hearing specialist (baleen whales)
LKARTS	Private consultant company in Norway
LMR	Living Marine Resources program of USN
MDTAG+	DTAG core unit, ARGOS satelitte transmitter and Fast GPS logger
MDTAG++	DTAG core unit, ARGOS satelitte transmitter, Fast GPS logger and video logger.
MMO	Marine Mammal Observer
MOBHUS	small boat, Man-Overboard-Boat of HUS
MOD	Ministry of Defence
MSC	Marine Science & Communication
NARA	Norwegian Animal Research Authority (Mattilsynet)
NAVFAC	Naval Facilities, branch of USN hosting LMR-program
PAS	Pulsed Active Sonar
PAM	Passive Acoustic Monitoring
PFM	Prey Field Mapping
PI	Principal Investigator
PTS	Permanent hearing Threshold Shift
SATT	SATelitte Tracking
SMRU	Sea Mammal Research Unit, part of St.Andrews University, UK
SL	Source Level (of sonar source)
SOC	SOCRATES II sonar source
SPLASH	Wildlife Computers Limpit splash tag (model SPLASH10-F-333)
TAG	Tagger
TBD	Tag Boat Driver
TNO	NL Organization for Applied Scientific Research
TT	Tag Technician
TTS	Temporary hearing Threshold Shift
UBA	German Environment Agency
USN	US Navy
VHF / DDF	Digital Direction Finder using VHF
XBT	eXpandable BathyThermograph, probe to measure temperature profile of water column
XO	Executive Officer

3S4 PROJECT BACKGROUND AND OBJECTIVES

Modern long-range anti-submarine warfare sonars transmit powerful sound pulses which can have a negative impact on marine mammals. The biological relevance or severity of behavioral responses depends upon the duration of responses. A key challenge exists to extrapolate results from the short duration (30-40min) experimental exposures used to date in BRS studies to the typically longer duration operational activities of navies using sonar typically lasting 6-12 hrs. If animals habituate over time, the severity of behavioral responses based on BRS would be overestimated. Conversely, if animals sensitize over time, the severity would be underestimated. Furthermore, all BRS research so far, except the third phase of the 3S-project, has been conducted using pulsed active sonars (PAS), typically transmitting at a 5-10% duty cycle. Recent technological developments imply that, in the near future, naval sonars will have the capability to transmit almost continuously (Continuous Active Sonar, CAS). This technology leads to more continuous illumination of a target and therefore more detection opportunities, even at a substantially lower source level. However, the feature of high duty cycle of CAS raises imminent questions about the environmental impact of such sonar systems. Robust results from sperm whales investigated during 3S3 (2016-2023) indicate that the severity of reduced foraging response during CAS exposures is similar to responses to PAS when the ping-by-ping cumulative signal energy is the same, but knowledge from other species is needed.

The objectives of the fourth phase of the 3S project (3S4) are to:

1. Investigate if exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals in killer whales, humpback whales and bottlenose whales; and
2. investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

The 3S4 study will address CAS vs PAS (objective 1) and longer vs shorter duration exposures (objective 2) by conducting both short- and long-duration CAS and PAS exposures to species for which the responses to short-duration PAS have already been investigated. The study is a 4-year project as the base option, starting January 2023, ending December 2026 with two 4 week field trials (October-November 2023 and October-November 2024). We are also planning an optional 6 month expansion of the project with a third trial in 2025 to investigate the effect of CAS vs PAS in northern bottlenose whales. This extension of the project is not currently funded.

3S-2023 CRUISE TASKS AND PRIORITIES

Primary tasks:

1. Tag killer whales with Mixed-DTAG+(+) and expose them to dose escalating CAS or PAS twice over an extended period (8 hrs).
2. Tag humpback whales with Mixed-DTAG+(+) and expose them to dose escalating CAS or PAS twice over an extended period (8hrs).
3. Tag killer whales with splash tags in the core operation area (higher priority early in the trial)

Secondary tasks:

4. Tag killer whales with Mixed-DTAG+(+) and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible)
5. Tag humpback whales with Mixed-DTAG+(+) and expose them to short duration CAS or PAS (mostly back up if long duration exposure is not feasible)
6. Collect echosounder data to monitor the prey field
7. Collect 24 h duration baseline data records of target species
8. Collect drone footage of tagged subjects for body condition characterization
9. Collect information about the environment in the study area (CTD, XBT)
10. Collect acoustic data using a towed array.
11. Collect sightings of marine mammals in the study area.
12. Perform sound source (SOC) long duration engineering test and harmonic characterization.
13. Collect herring samples around feeding whales.

Priorities:

- KWs are higher priority than HWs
- Primary focal whales are a higher priority than secondary focal whales
- CAS exposures are higher priority than PAS, but optimize contrast within each species
- Mixed-DTAG+(+) deployments are higher priority than splash tag deployments
- Primary tasks are higher priority than Secondary tasks.
- Secondary tasks should not interfere with our ability to accomplish the primary tasks.

3S4-CONSORTIUM

Table 1. The partners, sponsors and associated partners of the 3S4-project

3S4 partners	3S4-sponsors	3S4 Associated partners
FFI (NO)	*US Navy / LMR*	*Dalhousie Univ. (CA)*
TNO (NL)	*NL COMMIT*	*LK-ARTS, Norway (NO)*
SMRU (UK)	*FR DGA*	*CEREMA (FR)*
Univ. Iceland (IS)	*CA DRDC*	*Univ. Michigan (US)*
DRDC (CA)		*AORI (JP)*
		Marine Science & Communication (NL)
		Bundeswehr (GE)
		German Environment Agency UBA (GE)

OPERATION AREA

We have proposed to target focal species in areas and periods where killer whales and humpback whales aggregate to feed on herring in the herring overwintering area of northern Norway (Fig. 1). The operation area and period of the trial was determined based on a thorough analysis of expected weather conditions, available daylight, herring fishery activity and available knowledge on whale migration patterns.

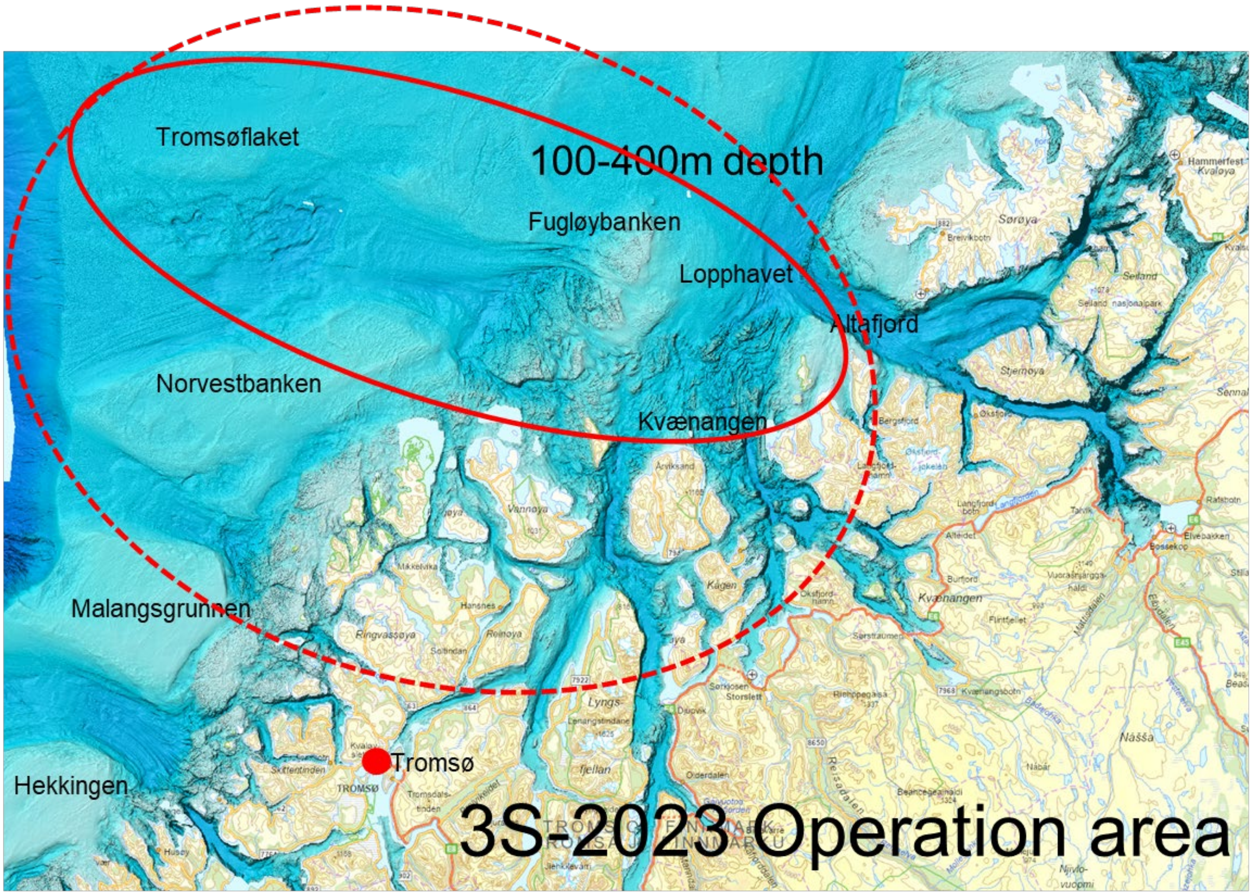


Figure 1. The 3S-2023 operation area will be Kvænanger-Lopphavet-Fugløybanken-Tromsøflaket-Nordvestbanken. These areas are 100-400m deep. The map shows the core operation area (solid circle) and outer operation area (dashed circle). Mobilization and de-mobilization will be in Harstad which is only a few hours transit from the core operation area.

SAILING SCHEDULE

Table 2. Sailing schedule of the 3S-2023 trial.

Date	***Time***	***Event***
Wed Oct 4th	*17:00* *19:00*	*Rendezvous in Harstad. General brief at Scandic Hotel Harstad at 17:00.* *A group booking is made with reference "FFI"* *Joint no-host dinner.*
Thur Oct 5th	*09:00*	*Embarkment HU Sverdrup II at Stangnes terminal, Harstad* *Loading and technical installation* *Bunkering of fuel and food supplies.* *Test VHF and Goniometer antenna placement*
Fri Oct 6th		*Finalize technical installation, training of MMOs, safety training of tag boat crew, brief of ship's crew, safety briefing* *Assess weather and fishery activity to decide on where we should start searching for whales.* *Calibration of the EA600*
Sat Oct 7th	*08:00* *20:00*	*Planned departure Harstad (or any sooner if possible)* *Transit to Vågsfjorden for engineer test of SOC-source and drill of operation. Transit back to port if needed.* *Transit to operation area if all systems GO*

		Switch to regular watch plan
Oct 8th – Oct 31st		**Fully operational**
Oct 19-20		Quick crew change in Tromsø. Exact time depends on weather and if we are doing an experiment. On/Off-going personnel have to be flexible
Wed 1st Nov	08:00	Transit back to Harstad Arrival Harstad, De-brief, de-installation and packing Celebration?
Thurs Nov 2nd	09:00 12:00	Off-loading. Disembarkment in Harstad Return travel

CREW PLAN

Table 3. Crew plan and roles during the 3S-2023 trial

1st period Oct 5th – Oct 19-20	2nd Period Oct 19-20 – Nov 2nd	Main role	Secondary roles	Affiliation
Petter Kvadsheim	Petter Kvadsheim	CO/CEE	MMO	FFI
Frans-Peter Lam	Frans-Peter Lam	XO/CEE	SOC / PAM	TNO
Patrick Milller	Patrick Milller	PI/TAG	MMO/TT	SMRU
Paul Wensveen	Paul Wensveen	TAG / SATT	MMO / TT	Univ.Iceland
Eef Brouns	Eef Brouns	SOC + hardware engineer	PAM / MMO	TNO
Mark von Spellen		SOC + hardware engineer	PAM / MMO	TNO
	Odile Gerard	PAM	MMO	DGA
Sander van Ijsselmuide	Martijn van Riet	SOC + software engineer	PAM / DM	TNO
Marije Siemensma	Jacqueline Bort	Lead MMO	DM	MSC / NAVFAC
Lars Kleivane	Lars Kleivane	TBD/ TAG	MMO	LKARTS
Rune Roland	Rune Roland	TBD	MMO	RRH
Ellen Hayward	Ellen Hayward	TT	SATT / MMO	SMRU
Alec Burslem	Alec Burslem	TT	SATT / DP / photo id	SMRU
Craig Reesor	Craig Reesor	PFM / MMO		DRDC
George Sato	George Sato	MMO	SATT / DP / photo id	SMRU
Stefan Ludwig	Mirjam Müller	Lead MMO	PAM	BUNDESWEHR/UBA

ROLES: CO=Commanding Officer, XO=eXecutive Officer, CEE=Exposure coordinator, PI=Principal Investigator, MMO=Marine Mammal Observers (visual and VHF tracking), SOC=SOCrates source operator, PAM=Passive Acoustic Monitoring, TT=Tag Technician, SATT=SATelitte Tracking (Goniometer, ARGOS), DP=Drone Pilot, PFM=Prey field mapping, TAG=Tagger, TBD=Tag Boat Driver, DM=Data Management.

MAIN COMPONENT OF THE TRIAL

HU Sverdrup II (HUS)

Figure 2. HUS

Length: 55 m
Max speed 15 knots
Crew: 7
Scientific crew: 15

HUS will be outfitted with the Socrates source and operating software, Delphinus towed array system, VHF and GPS-ARGOS tracking systems, tag boats with cradle for loading/off-loading. In addition HUS will also carry equipment to measure sound speed profiles.

Visual and acoustic search for marine mammals, VHF, GPS-ARGOS and visual tracking of tagged animals, behavioural observations of tagged animals, operation of the sonar source and preparation of the tags will be done from the HUS. HUS will also lodge the research team and be the command centre for the operation.

Tag boats

We will have two tag boats available. MOBHUS I is a water jet propulsion Man Over Board (MOB) boat deployed using a dedicated davit. MOBHUS can be deployed and operated up to sea state 4. MOBHUS is the main tag boat. The second tag boat is a brand new 8m RHIB that TNO has acquired. It will be stored in a crib on top of the TNO container on the back deck and deployed using the ship's crane. It can only be deployed in calm sea conditions (up to sea state 2). The tag boats will be launched when whales are sighted and weather permits tagging attempts. In the tagging phase the tag boat will carry tagging gear (ARTS, pole, tags with necessary accessories), documentation sheets, GPS and camera. MOBHUS is installed with navigation system, VHF and AIS. The tag team will usually consist of three people; a driver, a tagger and someone in charge of photo id/documentation.

Figure 3. MOBHUS (top) and TNO-RHIB tag boats (bottom)

Sonar source – SOCRATES

The multi-purpose towed acoustic source, called SOCRATES II (Sonar CalibRAtion and TESting), will be used and operated from the HUS. This source is a sophisticated and versatile source that was developed by TNO to perform underwater acoustic research and has been used as a prototype LFAS source on board of the M-frigates of the Royal Netherlands Navy. Socrates has two free flooded ring transducers, one ring for the frequency band between 0.95 kHz and 2.35 kHz (source level 214 dB re 1 µPa @ 1m in PAS mode), and the other between 3.5 kHz and 8.5 kHz (source level 199 dB re 1 µPa @ 1m). It also contains one hydrophone and sensors to monitor and record depth, pitch, roll and temperature. Because of risk of cavitation and damage to the source, it must stay below cavitation depth during operation.

Figure 4. The SOCRATRS source (left) and Delphinus array (left) deployed of HUS.

Acoustic array – DELPHINUS

During the trial, the TNO developed Delphinus array system will be used. It will be deployed from the HUS to primarily acoustically search for target marine mammals. The Delphinus is a 74 m long single line array containing both LF and UHF hydrophones. 18 LF hydrophones are used for the detection and classification of marine mammal vocalization up to 20 kHz. Three UHF hydrophones with a total baseline of 20m are used for the detection, classification and localization of marine mammal vocalizations up to 160 kHz. Additionally there is a single triplet (consisting of 3 UHF hydrophones), which will be used to solve the left-right ambiguity for the localization. The array is also equipped with depth and roll sensors. During exposure experiments the Delphinus system will not be used. When a CTD sensor is being used, both the Socrates and Delphinus need to be out of the water.

Whale tags, deployment and tracking systems

Subject whales will be tagged with Mixed-DTAG++s (MDTAG). The tag is attached by 4 suction cups, and can be programmed to release after a specified deployment duration or at a set time. The MDTAG contains a core DTAG unit built at the University of Michigan with stereo hydrophones, 3-axis acceleration, 3-axis magnetometer information as well as depth. DTAG audio will be sampled at 240kHz and other sensors at 250 Hz, allowing a fine reconstruction of whale behaviour before, during, and after sonar transmissions. In addition the MDTAG also contains a LOTEK GPS-ARGOS unit, and Little Leonardo video unit and a VHF beacon (148Mhz band).

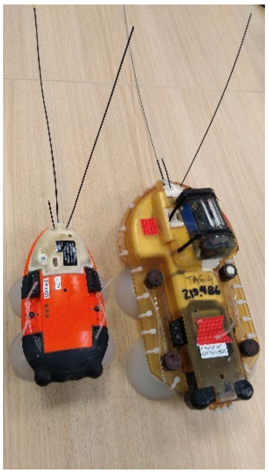


Fig 5. Integrated Dtag3 (left) and mixed-Dtag+(+) (right).

The LOTEK unit logs Fast-GPS snapshot information used to calculate positions, and relays these GPS data via Argos transmissions. In additional to ~7 hours of video, the Little Leonardo video unit records 24 hours of depth and 3-axis accelerometer data, as a backup in case of data problems with the Dtag core units.

These additional sensors help us track the whale during experiments using the GPS-Argos transmissions, and help us to find the tag when it has released from the whale using Argos locations. GPS positions result in a more detailed track of the whale and video data in the MDTAGs are useful to observe behaviour, and prey field characteristics. We have 6 MDTAGs available, in addition to 2 integrated DTAG3-units that also have the LOTEK GPS-Argos unit and an integrated VHF transmitter (219Mhz band), but no video logger.

In addition to the suction cup tags, we will have 6 Wildlife Computers SPLASH10-F-333B satellite tags with Fastloc GPS and depth sensors. These tags will be used to help us locate potential study subjects, and could also possibly be secondary or non-focal study subjects. However, as we are not sure that behavioural responses can be consistently documented using satellite tags alone, our preference will always be to have a suction-cup tagged whale as the primary focal subject of experiments. A dedicated team will focus on programming and deployment of the satellite tags.

Tag tracking systems will include handheld Yagi-Uda antennas and Automatic Direction Finder (ADF) for VHF signals, and Goniometer antennae for receiving Argos transmissions directly on the vessel. Two different Goniometer antenna systems will be used to receive the ARGOS signals directly on the Sverdrup, one with a high-gain antenna for GPS decoding, and one with a low-gain directional antenna for Automatic Direction finding. The ideal mounting positions for these antennae need to be established and tested at the start of the trial. Finally Argos quality, and GPS-Argos quality locations relayed via satellite can be received from the ARGOS webserver. As much as possible, input from these tracking systems will be automatically made available to the CEE tool (see below).

MMO platform

The MMO platform on the flybridge of the SVERDRUP will be set up with 2 big-eye binoculars, handheld binoculars, a rugged laptop with the program IFAW Logger for recording visual sighting information, and the DFHorten ADF station. For rough weather and when the radar is on, a backup station should be made available on the bridge. During nighttime sonar exposures, mitigation observers will use Pulsar Merger LRF XP50 thermal imaging binoculars using the optimal setting for detection of marine mammals and their blows as determined during pre-trial tests.

EA600 Echosounder

HUS has a Kongsberg Maritime EA600 hydrographic echosounder mounted on a bracket under the hull. It operates on 12kHz, 38kHz and 200kHz. The transducer is connected to transceiver deck unit in the transducer room and wired to the control unit (computer) in the main operation room. The plan is to replace the GPT and control unit to optimize for water column biomass detection, and use the echosounder at 38kKz and 200kHz opportunistically for prey field mapping. The system needs backscatter calibration before the start of the trial.

UAV Drones

During daylight hours, when weather conditions allow, drones will be used to take calibrated measurements of the size and body shape of focal tagged whales. Drone footage is also valuable for presentation and outreach purposes. Ideally the UAV drone can be launched and recovered from Sverdrup, but some testing is needed to confirm this capability. Otherwise, it will need to be launched and recovered from the tag boats. The UAV drone will fly 20m above each tagged whale for several surfacings, before returning to Sverdrup for recovery. DJI Phantom 4 Pro UAVs with custom mounted LIDAR systems will be launched from the Sverdrup when we are in close proximity to the tagged whales. Ideally drone flights would occur during the tagging, post-tagging, or pre-exposure baseline period, but could also be done during the post-exposure monitoring period. Drone flights require a team of 2, the drone pilot and a drone handler.

CEE tool

The CEE tool is a new developed software package designed to support the Controlled Exposure Experiments. It features:

- Bathymetry (depth-contours) and coastlines.
- Own ship track
- AIS tracks of other platforms in the area
- Range-Bearing tool
- Manual input of positions (markers)
- Tracks of a tagged whales composed of the following sources:
    - Position information from the ARGOS satellites (both ARGOS cross bearing and GPS quality positions).
    - Position information via the Line-Of-Sight Goniometer.
    - Position information via manual user input (for example Visual detections)

The tool consists of two screens, one screen shows a geographic overview of the above mentioned features and includes the user interface tools to edit some of these data.

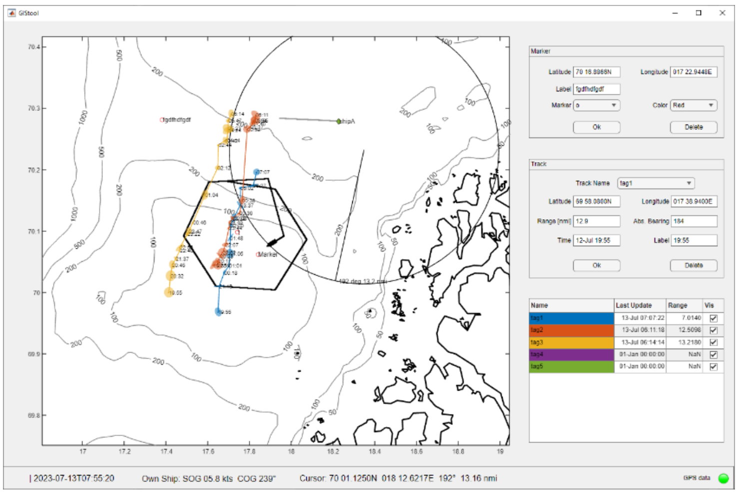


Figure 6. Example of CEE tool with simulated data. These pictures (July 2023) are from the current version of the CEE tool, that is still in development.

A second screen, provides an overview of the historic and predicted range to the tagged whales, and can be used to tune the course of H/U Sverdrup II to comply with the planned experimental design.

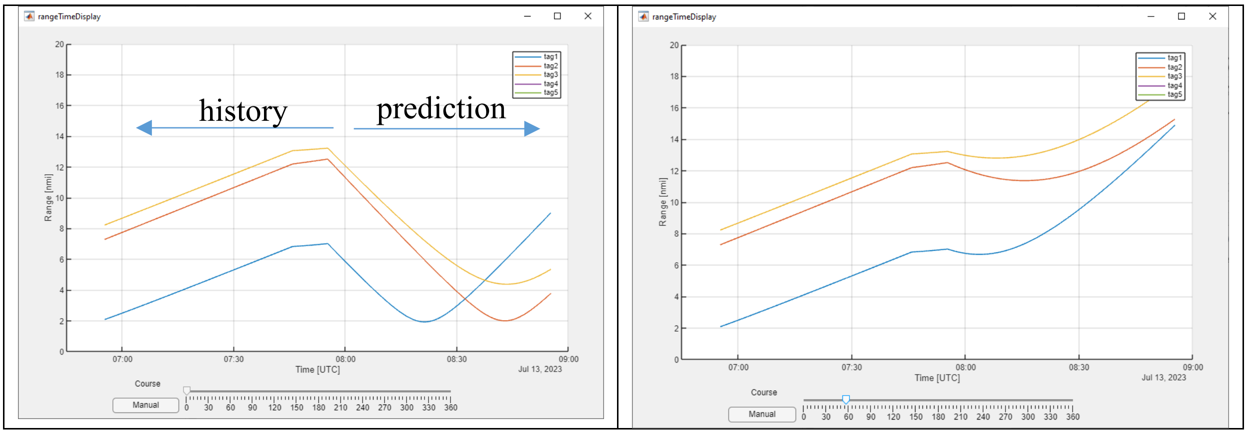
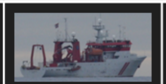
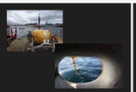
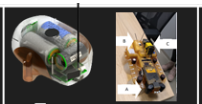
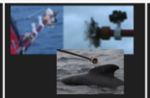


Figure 7. Example of CEE tool Range-Time display. It depicts the range to a whale track for the last hour and a predicted range for the next hour based on; the last known whale position, H/U Sverdrup II speed of 8 kts and a user defined course. In the left figure this is course 000° while for the right figure this is course 060°.

Our ability to conduct the experiments as planned, partly in the dark, depends on how well the telemetry tracking of the tagged whales works. This was tested during the 3S-baseline trial in Iceland this summer. Depending on tag placement we can expect Argos position (satellite cross-bearing) updates 1-2 times pr hr, but Argos GPS position updates via Argos only once every 2-3 hrs. However, when we are within the range of the real-time Goniometer tracking system, we can expect GPS position updates as often as every 5-10min. The range of this system depends on the tag placement and on the performance of the receiving antennas on the Sverdrup. If similar performance is achieved on the HUS as on the much smaller vessel in Iceland, we might receive regular successful GPS positions at 8-10 nmi distance from the tagged whales. Actual performance needs to be tested at the start of the 3S4 trial. The position updates from Argos or the Goniometer are automatically read by the CEE-tool, whereas visual position fixes from Logger has to be manually entered into the tool.

RESPONSIBILITIES

Table 4. Responsible partner for staffing, permits and equipment during 3S-2023.

	 Staff	 Vessel	 SONAR	 MMO	 Ocean.equip	 Tag boat	 Tags	 Tagg Equip	 Tracking	 CEE tool	 Permits
FFI	Kvadsheim Roland Kleivane	RV HU SverdrupII		Wind shield VHF-comm Ant. Mast	EA600, 38/200kHz. Saiv CTD	MOBHUS II			2 HDDF VHF yagi Cables	Event Logger NAVIPAC	FFI IACUC NARA-permit FOH Subdanger
TNO	Lam Brouns, Spellen, Ijsselmuide, Riet, Siemensma		SOCRATES Delphinus		XBT	8m RHIB				Integrated CEE tool	LMR OBSN warning
SMRU	Miller, Hayward Burslem, Sato			2 units Pulsar Merger XP50 Big eyes Logger Laser range Compass, Protractor Binoculars			**6 mixed-dtags** w/ LOTEK FGPS-ARGOS, VHF, L. Leonardo Video-data loggers **6 WC Splash10**-F-333B tags	Handheld poles ARTS Digital cameras Drone	HDDF VHF-yagi VHF hand Cables Goniomet		SMRU Ethics
Univ Iceland	Wensveen										
LKARTS	Kleivane			1 units Pulsar Merger XP50				ARTS	?		
Univ. Michigan							6 dtag core units 2 dtag3				
AORI							1 Little Leonardo Video-data loggers				
DRDC, DGA, Univ Dal, NAVFAC, UBA, BW	Reesor, Gerard, Trigg, Bort, Müller, Ludwig										

DAILY WORK PLAN

The 3S-2023 trial is a complicated operation which requires different teams to work together in a highly coordinated manner. The different teams include: visual teams, acoustic teams, tagging teams, cruise management and the navigators on HUS.

The operation goes through different phases which require very different staffing from the different teams. The main phases are: search phase, tagging phase, pre-exposure phase, exposure phase and post exposure phase. After the tags have detached from the whales and have all been retrieved, we start over searching for new subject animals.

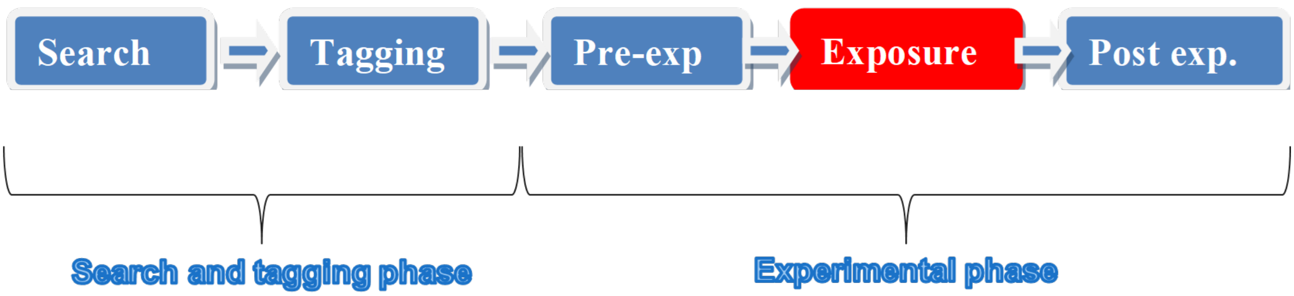


Figure 8. Main phases of the operation.

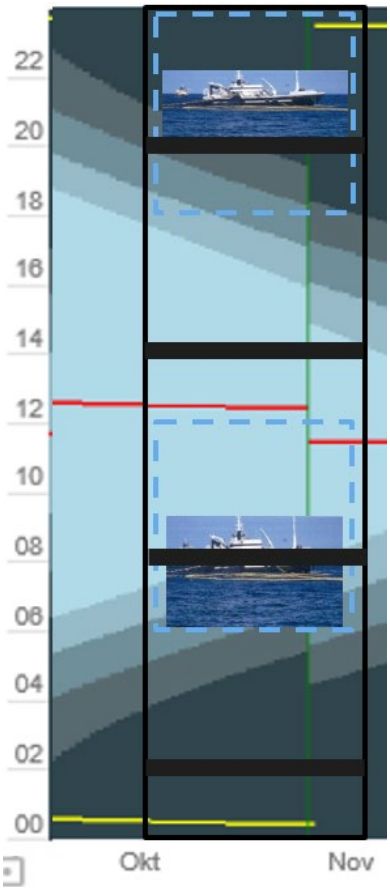
The complexity of the operation requires a structured watch plan, which considers a minimum staffing requirement from the different teams, but we also have to be flexible when the operation moves into the more labour demanding experimental phases. It also requires a well-defined chain of command and communication plan.

Planning meetings

Every day at 07:00 the chief scientists from the main 3S partners (Kvadsheim, Lam, Miller, Wensveen) will convene on the bridge to plan the activities for the coming 24 hrs. Search areas and patterns, species priority, tag priority, logistical constraints, crew dispositions etc. will be discussed and implemented in the daily plan. The plan for the day will be announced on a poster board before 08:00. Adjustments to the daily plan will be made by the CO and XO between the daily meetings as needed. If you have an idea or would like to bring something to the attention of the cruise management team, you might address one of the chief scientists at any time. Occasionally, the cruise leader may call for a plenum meeting with the entire scientific crew.

Watch plan

The entire crew will follow a basic regular seamen's watch plan of 6 hrs on and 6 hrs off, with change of watch at 8 and 2 am and pm, coordinated with the meals on-board and following the schedule of ship's crew. This will cover the basic staffing requirement in all phases of the operation. The available daylight drops from 11hrs at the start of the trial to only 6 hrs at the end (figure 9), so the visual and tagging effort has to be adapted to this in search and tagging phases. However, we target to tag whales feeding around purse sein fishing vessels, so tagging is possible also in the dark period. The fishing happens in two waves from 06-12 and 18-00 with peaks from 06-09 and 20-22.



Watch period	08 – 14	14 – 20	20 – 02	02 – 08
Kvadsheim				
Lam				
Miller				
Wensveen				
Brouns				
Spellen / Gerard	Odile	Mark	Odile	Mark
Ijsselmuide / Riet				
Siemensma / Bort				
Kleivane				
Roland				
Hayward				
Burslem				
Reesor				
Sato				
Ludwig / Muller				

Figure 9. Right: watch schedule for the 3S team. Left: Sungraph for the operation area/period. Local time on the Y-axis, red and yellow lines are noon and midnight local time, respectively. The periods of daylight, twilight and darkness are indicated. The black boxes indicate watches (08-14, 14-20, 20-02, 02-08) with thick black lines indicating watch transition times, the blue dashed boxes indicate periods of expected fishing activity (06-12 and 18-00), with expected peak activity indicated by the fishing vessel (06-09 and 20-22).

Working in this area at this time of year, and tagging around fishing vessels is a bit new to us. We therefore have to stay flexible and make modifications to the watch schedule if needed to optimize the effort.

It is part of our 3S-culture that the full team is expected to arrive on its post 10 min prior to the start of your watch. This is to avoid any gaps in the effort, and to allow for organized information exchange between teams. The new team will be ready and the retiring team is dismissed in time.

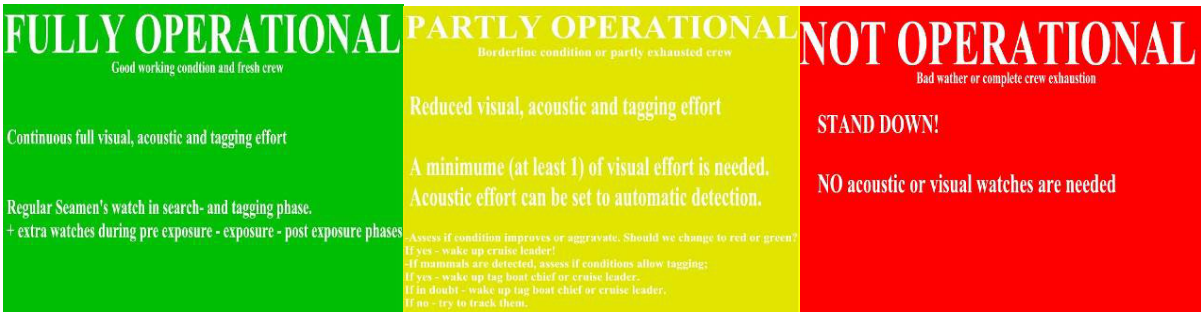
Tag teams consist of three people, a driver, a tagger and someone in charge of photo documentation and drone footage. Depending on which team is on watch the tag teams will be (driver-tagger-photo/drone): Roland – Wensveen – Burslem during the 14-20 and 02-08 watches, Kleivane – Miller – Sato during the 08-14 and 20-02 watches.

The MMO effort included visual search for target species during daylight hours, VHF-tracking of tagged whales and mitigation monitoring during sonar exposures. A lead MMO will organize the effort and coordinate availability of secondary MMOs.

Kvadsheim and Lam are CEE coordinators on opposite watch shifts, Hayward and Burslem are tag technician on opposite shifts. Spellen/Brouns, Ijsselmuide / Riet will be operating the sonar systems. Reesor/Trigg and Ijsselmuide / Riet will be trained to monitor the echosounder recording system.

Operational status

In extended periods of good weather, and if we are successful in finding animals and tagging them, there is a risk that the work load on the team will be very high, and that eventually we will all suffer from collective exhaustion. In these periods, the basic watch plan has to be considered to be normative. It is better to have some level of search effort at all times rather than periods with no effort at all.



<u>Figure 10.</u> Operational status green – we are fully operational with continuous full visual, acoustic and tagging effort. Operational status yellow – we are partly operational with reduced effort on visual, acoustic and tagging effort. Operational status red – we are not operational, everyone can and should rest!

Increased risk to personnel in some phases of the operation, and increased risk of reduction in the quality of the data collected in other phases are factors which also have to be considered carefully in these periods of intense work load. Thus, the cruise leader (CO) may decide to reduce effort during search and tagging phase to rest the crew. Because of this risk of crew exhaustion, the cruise leader may also reduce effort in periods of bad weather or in dark periods without fishing activity in the area. To make sure everyone is aware of the operational status a traffic light system will be implemented. The operational status will be clearly indicated in the operation room and on the bridge.

DATA COLLECTION

Concept design and data analysis

The objectives of the fourth phase of the 3S project (3S4) are 1) to investigate if exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals in killer whales, humpback whales and bottlenose whales; and 2) investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

In the 3S4-2023 trial, both of the objectives will be addressed with behavioural response data collected during 8-hour exposures to killer and humpback whales. We will alternate CAS and PAS sonar, and the first objective will be addressed by comparing responses to those two stimuli types. Because each 8-hr exposure will be with different subjects, each exposure session should be as consistent as possible, following procedures specified in Table 5. In case long-duration exposures prove to be impractical, objective 1 can be addressed using shorter duration exposure alternating CAS vs PAS within the same subject.

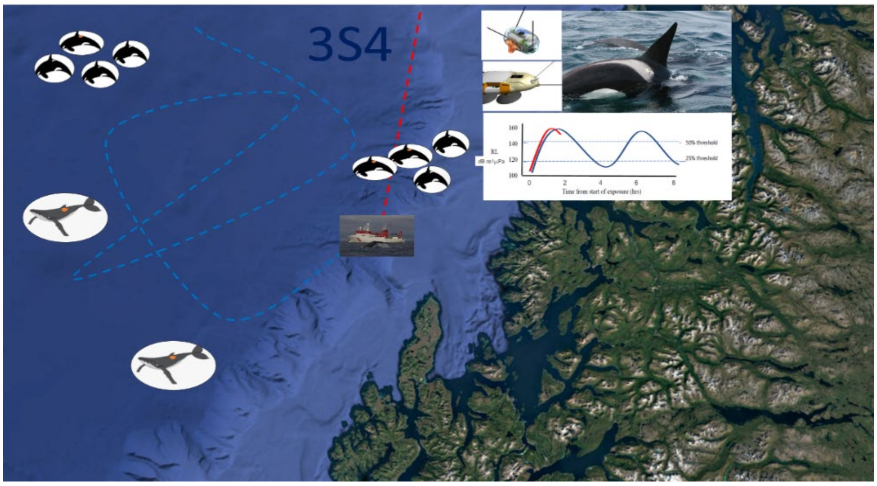


Figure 11. Conceptual design of the 3S-2023 experiment. Killer whales and humpback whales will be tagged with Mixed-dtag+(+) or limpet splash tags and exposed to CAS or PAS sonar over short or long periods. The short-duration exposures are the first part of the long duration exposures.

The second objective will be addressed from the same set of 8-hr exposures. Behavioural changes during the first vessel approach to the tagged whale will be compared with later changes to quanitfy the effect that long-duration exposure may have (Figure 12). Because received level (RL) of the sonar affects animal responses, it is important that a second approach to each tagged subject is accomplished during the 8 hour exposure period. That will enable a direct comparison of how the time since start of exposure might modulate responsiveness at a given received level.

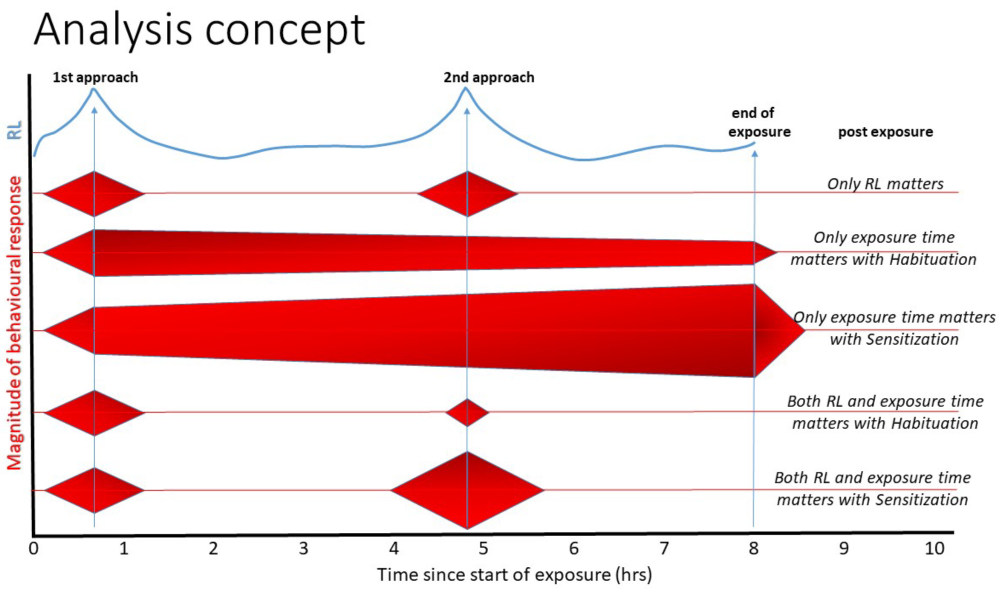


Figure 12. Schematic illustration of the data analysis concept for 3S4. For each experimental sonar treatment, the magnitude of behavioural change (compared to baseline behavior; shown in red) will be quantified using statistical methods like behavioral state modelling or Mahalanobis distance, or scored by an expert panel. The interpretation of different hypothetical outcomes in terms of drivers of response (RL versus time effects) are indicated (text to the right).

Experimental Cycle

The planned timeline for each experiment is detailed in Figure 13. Each experiment contains search and tagging phases, and an experimental phase which includes specified pre-exposure, exposure, and post-exposure periods.

Figure 13. *Timeline of the 3S4 exposure experiments with a two focal animal scenario (top panel) and a one focal animal scenario (lower panel). The default tag release time should still be set to 24hrs to allow for some extension of the baseline period or delays in the experimental program.*

2 focal animals scenario

Time (hrs)				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Phase	Tagging						Baseline								Exposure								Post exposure					
Source	Off														ON								Off					
Events	T0; 1st tag on T0-T2; 2hr 2nd tagging period T2-T3; 1hr post tagging T3-T11; 8 hrs baseline - HUS tracks F1 HUS stays >1km from focal whales														T11; 5min ramp up T11; 1st approach F1 HUS reposition T13; 1st approach F2 HUS reposition T15; 2nd approach F1 HUS reposition T17; 2nd approach F2								HUS stays >1km from focal whales T21; 1st tag off T23; all tags off Tag recovery					

1 focal animal scenario

Time (hrs)				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Phase	Tagging						Baseline								Exposure								Post exposure					
Source	Off														ON								Off					
Event	T0; 1st tag on T0-T2; 2hr 2nd tagging period T2-T3; 1hr post tagging T3-T11; 8 hrs baseline - HUS tracks F1 HUS stays >1km from focal whale														T11; 5min ramp up T11; 1st approach F1 T12-T15; HUS stays 10-30 km from F1 HUS reposition T15; 2nd approach F1 T16-T19 HUS stays 10-30km from F1								HUS stays >1km from focal whale T21; 1st tag off T23; all tags off Tag recovery					

Search and tagging phase

Searching for whales will be done visually and using the DELPHINUS towed array. When possible, we will seek contact with fishing boats. Search locations may also be aided by positions provided by satellite tags deployed on killer whales. During the search phases, the tag technician team should prepare MDTAGS to be fully charged and as prepared as possible.

Once whales are sighted and weather and light conditions allow for tagging, tags should be fully prepared, and the tag boat deployed to approach the whales.

The current experimental design require tag retention times on the whale close to 24 hrs, which is longer than most DTAG deployments. Tag retention time was tested during the baseline trials in Iceland and Mixed-DTAG+ had better retention time than the integrated DTAG3. The retention time is also better when the tag was deployed to adult animals compared to juveniles. We should therefore prioritize to use the mixed-DTAG+(+) units instead of the DTAG3, and focus tagging effort on adult animals as much as possible.

Suction cup tagging will primarily be done using handpoles, which maximizes control for optimal tag placement and orientation on the whale. Based upon our pilot tests in Iceland, ideal placements are 1) on top of the body between the dorsal fin and blowhole with antennas facing backward, and 2) at the base of the dorsal fin with antennas angled slightly up. It is expected that handpole tagging should not be limiting when we tag near fishing vessels. If handpole tagging is limiting during daytime periods away from fishing vessels, the MDTAGs can be deployed using the ARTS tagging system, but the video loggers would need to be removed for ARTS tagging.

The satellite tags will be deployed on killer whales using either the Daninject or ARTS tagging system using state of the art procedures. Barbs must be sterilized prior to deployment. Tags should be deployed targeting the dorsal fin, and only adult animals should be targeted for satellite tag deployment. Deployment of satellite tags will be a priority early in the trial, but we should avoid deploying more than 2 satellite tags during any one whale encounter.

During each tagging event, the response of the whale will be scored as follows:
0. No reaction: whale continued to show the same behaviour as before the tagging attempt
1. Low-level reaction: whale modified its behaviour slightly (e.g. dove rapidly or small tail slap
2. Moderate reaction: whale modified its behaviour in a more forceful manner over a short duration (single breach or spyhop), or a low-level reaction over a longer period (moving away)
3. Strong reaction: whale modified its behaviour in a succession of forceful activities (successive percussive behaviours such as breaches or strong tail slaps)

A tagging data sheet will be taken on the tagboat, and should be completed for each tag deployment, including time, location, size of animal, reaction, location of tag on the body, tag system and settings, and number of VHF beeps/surfacing. When possible, pictures should be taken of the tag on the whale body after attachment.

The first tagged whale will be considered the FOCAL-1 whale and MMOs on SVERDRUP will track the whale and stay 1-2 km distance. If additional tags are deployed, the FOCAL-1 or FOCAL-2 may be changed depending upon tag attachment and species. All tagging effort will cease a maximum of 2 hours after the first tag is attached, at which time the tag boats will be recovered. MMOs on the Sverdrup should continue to track the FOCAL 1 whale and manoeuvre Sverdrup to stay 1-2km away from the FOCAL-1 whale.

Experimental phase

After tagging has finished, HUS will track and follow the tagged whale at 1-2km distance for pre-exposure data collection of 8 hours (to match the exposure duration). When daylight allows, visual tracking should also take place during this period.

Table 5. Summary of 3S4 exposure protocol specifications.

Parameter	Specification
Exposure types	CAS or PAS, CAS is higher priority
Target species	Killer whales (KW) or humpback whales, killer whales are higher priority
Target sample size	N=26 KW, N=26 HW
Exposure duration	8hr max exposure; long duration exposures fixed at 8 hrs with shorter duration CAS-PAS contrast as back up
Exposure range	CPA – 30 km max, 10-30km between approaches
Closest point of approach (CPA)	Target 1000m CPA for both approaches for both KW and HW
Target exposure range dB	130-160 dB SEL_{20s} re $\mu Pa^2 \cdot s$
Number of focals	N=1-2, target is 2 (+ non focals), preferably in separate groups
Focal vs non focal range cut off	As a rule of thumb – F2 becomes non-focal if separated from F1 by less than 2km and more than 30km.
Approach distance	10km
Approach speed	8 knots
Approach duration	40min to CPA
Approach trajectory	Initial course of the source vessel should be set to intercept future CPA at a 45deg angle in front of the whale's heading. During approaches turns are allowed twice (max 30 deg) towards new updated CPA estimate until 3km range, after that the source vessel are only allowed to turn away from the animal towards target CPA.
Number of approaches	N=2 to each focal
Temporal approach separation	Approximately 4hrs
Max SL and ESL	CAS/PAS ESL_{20s} =214dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ SL_{CAS}=201, SL_{PAS}=214 re 1 $\mu Pa^2 \cdot m^2$
Ramp up	ESL_{20s} 154-214dB re 1 $\mu Pa^2 \cdot s \cdot m^2$ within 5min in linear steps for both CAS and PAS, after >5min shut down - restart ramp up
Transmitted signal	1300-2000 Hz HFM
Pulse repetition time	20s
Pulse duration	CAS 19s, PAS 1s
Mitigation action zone	500m ship-based monitoring range using visual observers equipped with thermal binoculars during nighttime
Shut down range	If any marine mammals are detected within 100m of the source, it will be shut down
Max expected weighted exposure levels for non-focal animals (SEL_{20s})	100m shut down range implies max 174dB weighted SEL_{20s} re 1 $\mu Pa^2 \cdot s$ for LF cetaceans and seals, max 149dB for HF cetaceans and 144dB for very high frequency cetaceans for 1-2kHz non-impulsive sounds
Max expected weighted exposure levels for focal animals (SEL_{cum})	1000m CPA implies max 178dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for humpback whales and max 153dB weighted SEL_{cum} re 1 $\mu Pa^2 \cdot s$ for killer whales
Weighted TTS and PTS onset according to Southall et al. 2019	For LF cetaceans (humpbacks and other baleen whales) TTS=179dB, PTS=199dB re 1 $\mu Pa^2 \cdot s$. For HF cetaceans (killer whales, pilot whales, sperm whales and dolphins) TTS=178dB, PTS=198dB re 1 $\mu Pa^2 \cdot s$. For very high frequency cetaceans (porpoises) TTS=153dB, PTS=173dB re 1 $\mu Pa^2 \cdot s$. For seals TTS=181dB, PTS=201dB re 1 $\mu Pa^2 \cdot s$.

Near the end of the baseline period, HUS will move to ~10km away from the whales to start the exposure phase which starts when the Socrates source starts active transmission and ends when transmission ends after 8hrs. The target is to approach each focal whales twice from 10km distance using CAS or PAS transmissions. There could be 1 or 2 focal whales during each exposure experiment.

Table 6. Treatment order during the sonar exposure experiments. The order is optimized to prioritize CAS and maximize the contrasts between CAS and PAS. Given all the new components of the operation, we will do a 'dry-run' of the experiment once without transmitting sonar.

Experiment	Treatment	Experiment	Treatment
1	*Experimental control, no sonar	2	Short-Long duration CAS
3	Short-Long duration PAS	4	Short-Long duration CAS
5	Short-Long duration PAS	6	Short-Long duration CAS
etc	etc	etc	Etc

** The idea is to do a no-sonar run first to test the experimental procedures before we ensonify the environment for 8hrs. The no-sonar run will be conducted with 2hrs baseline, 8 hrs simulated exposure and 2 hrs post-exposure. Tag release time should be 12 hrs. If low cost the duration of the no-sonar session can be increase to 24 hrs so that the data can be used to characterize the diel cyvle. If the no-sonar session is not completed by the first week of the trial, there is a decission point to skip it or not.*

We should avoid exposures during feeding around fishing vessels. This is an unusual context which might have limited application elsewhere, and it could also be complicated to achieve the experimental design due to navigation constrains. To avoid it, we can do a focal 2 approach with lower level exposures first if there is only one focal and that animal is feeding around a fishing vessel when the experimental phase is planned to start. We can also to some extent be flexible with the baseline period and increase it by 1-2 hrs. This implies extending the pre-programmed total tag release time to 24 hrs, and before deciding to extend the baseline period and delay the exposure assess if we can rely on the tag attachment (good stick on adult animals with good placement).

Tag retention time was tested as planned during the 3S-baseline trial in Iceland (p23). The mixed DTAG +(+) do meet our requirement, but retention times beyond 24hrs was not tested, and can't be expected. From the test in Iceland, it looks like the integrated DTAG3 is not meeting our requirement for retention time. If we end up having to use them, we should consider to change the experimental protocol. This does not mean shortening the current experimental design (Figure 13). We need to switch to a short duration CAS-PAS protocol (task 4 and 5) using an experimental design similar to the 3S3 CAS-PAS experiments on sperm whales (Isojunno et al. 2020; Kvadsheim et al. 2021).

When the exposure period has ended and the Socrates has ceased transmissions, the HUS will return to follow the FOCAL-1 whale at 1-2 km distance. Observations will continue until the tag detaches, at which point the FOCAL-1 tag and any other tags will be recovered.

Marine mammal risk mitigation during sonar exposure

During active sonar transmissions, the responsible CEE coordinator (Kvadsheim or Lam) will assure that no marine mammals are closer to the source than the 100m required by the permit. MMOs on the source vessel HUS will monitor the vicinity of the ship, focusing on the direction of travel. During sonar transmissions in the dark, marine mammal observers will use the Pulsar Merger thermal binoculars which enable them to detect marine mammals in the dark.

If any animals are approaching the 100m safety zone, an emergency shut-down of sonar transmission will be ordered. The source might be switched back on as soon as the animals are out of the danger zone. Sound exposure experiments will also be terminated if animals show signs of distress, disorientation or extreme responses, such as consecutive breaching behavior, and also if the animals swim dangerously close to the shore or enter confined areas that will strongly limit their escape routes.

The 100m shut down range implies maximum sound exposure levels over the 20s transmission cycle (weighted SEL_{20s} dB re 1 uPa2·s) of 174dB for humpback whales and max 149dB for killer whales in the 1-2kHz band. However, the tagged focal animals will not be approached closer than 1000m. Computer simulations of the study design predicted that focal animals will experience maximum weighted cumulative sound exposure level over the entire 8hr period (SEL_{cum}; dB re 1 Pa^2·s) of 178dB for humpbacks whales and max 153dB for killer whales. These levels are well below established criteria for hearing injury in our study species (PTS=199dB re 1 uPa^2·s for humpback whales and PTS=198dB re 1 uPa^2·s for killer whales; Southall et al. 2019). The difference between the two species is caused by differences in the hearing weighting functions (Southall et al. 2019), i.e. killer whales have lower hearing sensitivity at 1-2 kHz than humpback whales. Other marine mammals expected to occur in the area (seals, porpoises, dolphins and other baleen whales) will also be well under the injury criteria with these planned risk mitigation measures.

The decision to stop transmission outside the protocol is made by Kvadsheim or by Lam and Miller whom he has appointed to be responsible for permit compliance in his absence.

Prey field mapping

The echosounder system will operate continuously and record data. The vessel will not be driven specifically for prey field mapping, rather data will be collected opportunistically. Two staff members on different watch periods will be trained to check the system is operating and recording properly during the trial, and will be trained how to restart the system in case it ceases working. The system should be checked during each crew change and once during each shift.

Sound speed profiles (XBT, CTD)

A temperature profile (XBT) should be taken by the source vessel (HUS) during all sonar runs (close to CPA). CTD profiles will be taken from the HUS after the end of the full experimental cycle. However, HUS cannot reduce speed beyond 3 knots when towing Socrates or Delphinus. After an exposure experiment, Socrates and Delphinus are usually recovered on HUS, which allows HUS to collect CTD profiles along the exposure path (close to CPA) using the CTD probe. CTD profiles should preferably also be collected on a routine basis to monitor the acoustic propagation conditions in the operation area. This will enable us to plan the acoustic experiments using transmission loss models (e.g. LYBIN or Bellhop).

BASELINE PILOT STUDY TRIALS

Baseline pilot study trials have been conducted in Iceland in the summers of 2021, 2022, and 2023, focusing on killer, humpback and long-finned pilot whales in a herring spawning ground near the Westman Islands, Iceland. These trials collect valuable baseline data on the natural behaviour and interspecific interactions of the study species.

Importantly, the pilot study trials used the same tagging (MDTAGS and integrated DTAGs) and Goniometer tracking equipment that will be used in the 3S4-23 trial. Detailed methodologies for the state-of-the-art use of the tools were thereby established, and data flows from the tracking systems were detailed to connect tracking data to the CEE tool. Performance of the tagging and tracking systems were carefully detailed during the pilot study trials, so that any limitations on 3S4 experimental procedures can be clearly understood and integrated into the 3S4-23 cruise plan.

CHAIN OF COMMAND

Operational issues

Operational planning is made by the trial management group (Kvadsheim, Miller, Lam, Wensveen) during daily meeting. Between meetings the CO/XO execute operational decisions. The cruise plan is the overarching management document, and should be followed as much as possible. Any deviations from the protocols specified in the cruise plan will only be made with consensus of all 4 chief scientists on board (Kvadsheim, Lam, Miller, Wensveen).

The cruise leader is the commanding officer on board and makes final decisions if consensus is not reached within the management group. However, the cruise leader is obliged to consult with the chief scientists of the 3S-partners on decisions affecting their area of interest or responsibility.

Safety issues

The captain of the ship or the first officer, depending on who is on watch, makes final decisions on any safety issues.

Permit issues

The permit holders are Petter Kvadsheim and Patrick Miller. They make final decisions on permit issues.

Sonar operation safety issues

A Risk Management Plan for the operation of Socrates and Delphinus is specified to minimize risk to this high value equipment. Final decisions on issues related to the safety of Socrates and Delphinus are made by the chief scientist of TNO (Lam).

DATA MANAGEMENT

A central server will be placed in the operation room and connected to the wireless network on-board. A file structure will be specified and all data should be uploaded to the server as soon as possible. Be aware that everyone can write to this disk, but everyone can also delete files, so pay attention when working on the master-disk. Data should always be backed up on local disks.

During the trial, some data should be sent via internet to project partners on shore. For example, Dtag data can be transferred to F. Samarra at U Iceland to begin acoustic analyses with the auditor team.

In the end of the trial the entire data record will be copied to all partners.

Folders in root:
Documents – TagData – Calibration - Logger - Socrates logs - Sound samples - Pics and videos - Software tools - Tagboat GPS - HUS GPS – SOC tracks – XBT/CTD – Drone data – Echosounder data

COMMUNICATION PLAN

In all phases of this trial the crew will be split in different groups (acoustic teams – marine mammal observation teams – tag teams - coordination/management) and platforms (HUS – TB1 – TB2 - OSVE. Coordination and thus clear communication between these units will be crucial, especially in critical phases. To ensure good communications there are VHF-communication equipment on all units. Tag boat must bring a spare handheld VHF. Close to the coast cell phones can be used as back up, but at high seas there is no coverage.

The radio call signals for the different units will be:

"Sverdrup"	Sverdrup (HUS) bridge (HQ) (answered by CO/XO, or captain/first officer if CO/XO not on the bridge)
"MOBHUS"	Water jet propulsion MOB (MOBHUS)
"SOCRATES"	Sonar operator on HUS (Socrates and Delphinus)
"Obs deck "	Marine mammal visual observation deck on HUS

A main working channel and an alternative channel in case of interference, will be specified.

During the tagging phase, communication to and from the tagging teams must be limited as much as possible.

Tag boats must report in to "HU Sverdrup" to confirm communication lines every hour! We are mostly operating in open ocean, and this safety procedure is an invariable rule. MMOs should also report over radio that they have safely arrived on station when they climb up there in the dark.

If not otherwise specified in the daily work plan the following channels should be used:

Main working channel	**Maritime VHF channel 72**
Alternative channel	**Maritime VHF channel 73**

RISK MANAGEMENT AND PERMITS

FFI has obtained necessary permits from appropriate civilian and military authorities for the operation described in this document. The operation area is entirely within Norwegian territorial waters or the exclusive economic zone of Norway. The operation is considered a military activity under the jurisdiction of Norwegian military authorities. RV HU Sverdrup II will carry a Royal Norwegian Navy Ensign and be placed under command of government official from The Norwegian Defence Research Establishment. Cruise leader Petter Kvadsheim is the commanding officer ultimately responsible for the operation.

A separate risk assessment and management plan has been made specifically for this trial. 5 types of risk are identified and mitigation measure and responsibility specified:

- Risk to the environment (injury to marine mammals)
- Risk to third party human divers
- Risk of impact on commercial activity (whale safari, whaling and fishery).
- Risk of damaging expensive equipment (Socrates and Delphinus systems)
- Risk to humans involved in the operation

Since the operation includes animal experimentation, we will operate under permits from the Norwegian Animal Research Authority (permit no 23/110085) acquired by Petter Kvadsheim and approval from the University of St. Andrews ethical committee acquired by Patrick Miller. The permits include tagging and acoustic exposure of up to 26 killer whales and 26 humpback whales according to the protocol described here. The exposure experiments are permitted under the condition that we maintain a 100m risk mitigation action zone around the sonar source during active transmission. If any animal enters this safety zone the sonar source will be shut down. The safety zone assures maximum exposure levels well below the established threshold of hearing impairment of the experimental subjects. Kvadsheim and Miller will be field operators responsible for permit compliance in the field.

Procedures to mitigate environmental risk will be implemented as described in this document, in the permit documents and in the risk management plan. Risk to humans should be minimized through the regular safety regime implemented for all relevant working operations on board. Procedures to mitigate risks to expensive equipment, such as the SOCRATES system and the towed Delphinus array have been established. All personnel involved in handling this equipment, including navigators, must be aware of the content of this plan. Risk involved in the handling and operation of this equipment is the primary responsibility of the TNO chief scientist.

PUBLIC OUTREACH AND MEDIA

Before departure the press office of all involved partners should be informed about the trial, and about our plan to on how to handle media. During the trial, media contact should be referred to the cruise leader (Kvadsheim) on HUS. An on-shore PR-contact will be appointed by FFI, and will serve as the POC for all inquiries from media.

There might be some local concern about our operation from fishing vessels and whale watching companies operating in the area. They will be informed about our operation, but if necessary we might do some public outreach meeting during the trial.

GENERAL ADVICE TO MEMBERS OF THE SCIENTIFIC CREW

The scientific trial you will be involved in is a unique experience. Make it enjoyable for yourself and others. Be positive and constructive by finding solutions to problems before complaining. Weather conditions will be the most limiting factor during the cruise. In October-November the air temperature will already be relatively cold at sea in these Arctic oceans (0-5 ºC). Make sure you bring high quality clothing for all layers. Floatation suit is mandatory for everybody working on the tag boats. However, it's what you wear under the suit which keeps you warm. A hat, gloves and shoes which keep you dry are your most important tools.

A watch plan will be specified, it is your duty to work when on duty, but also to rest when off duty. We must maximise the time available with good conditions to attempt as many experiments as possible. You should expect long hours of hard work while these good weather windows happen. You will have long hours of rest when weather conditions deteriorate.

Experimental methods and procedures have been fixed in advance, and need to be kept in compliance with permits. There is very little that can be changed without affecting the data being collected. If you can think of improvements, discuss them with the cruise leader and principal investigator first before implementing.

This cruise is not a whale watching cruise, so whenever you are on duty keep focused on your tasks. If you are off duty use well your resting period and do not disturb/distract the ones that are on duty. It is probable that you will share a cabin with other people, so keep it tidy and pleasant for everyone. If you have any problems please speak to the cruise leader directly and openly as soon as possible. A delay may make matters worse or cause ill feeling between work colleagues.

The food on the HUS is known to be very good. However, it might be a good idea to bring your favourite food goodies (*e.g.* tea, coffee, chocolate, cookies, etc.), and let us know if you have any diet restrictions. No alcohol is allowed on board at sea.

Prepare yourself mentally that we might be at high sea without even sight of land for weeks at the time. We might be out of cell phone range most of the time. Warn the people at home that you are still alive, even if you don't pick up their calls. The ship has continuous satellite based internet connection and internal wireless network, so communication with home should always be possible. However the bandwidth is limited so avoid downloading large files and switch off software updates. Do not use web based communication such as Skype. There are a few available computer stations on board, but these have to be shared. You are welcome to bring your laptop and connect to the network.
Be prepared!   ENJOY!   Good luck!

TRIAL READINESS REVIEW

The planning of this trial has been very thorough and has involved the full field team and other relevant experts to maximize our chances of achieving the trial and project objectives. All necessary permits have been acquired. All equipment, materials and staff required for the planned research effort have been obtained or are scheduled for delivery in time for the trial start. The 3S board approved this cruise plan on September 7th 2023 as ready for execution in the time-frame specified. However, in the period leading up to the start of the trial we still have to establish a detailed plan for the mobilization and test phase of the trial, establish a network of contacts within the fishing fleet, execute the public outreach plan, resolve how we can optimize prey field mapping with the EA600 on board the research vessel and establish a detailed protocol for the use of splash tags.

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D 3S-2023 Risk assessment and management plan

APPENDIX D

Risk assessment and management plan for the 3S-2023 research trial with HU Sverdrup II

Introduction

This document describes the risk identified for the 3S-2023 research trial. The trial will primarily take place off the coast of Northern Norway at Kvænangen-Lopphavet-Fugløybanken-Tromsøflaket-Nordvestbanken between October 5th and November 2nd 2023 using FFI research vessel HU Sverdrup II (HUS).

The objectives of the trial are to investigate if exposure to Continuous Active Sonar (CAS) leads to different types or severity of behavioral responses than exposure to traditional Pulsed Active Sonar (PAS) signals in killer whales and humpback whales, and investigate empirically if responses from short duration experiments predict responses from longer duration exposures conducted over an operationally relevant duration.

The objectives of the trial will be achieved deploying Mixed-DTAG+(+) or splash tags to killer whales and humpback whales and do short- and long-duration CAS and PAS exposures using real-time GPS location data of multiple tagged subjects. A high powered sonar source will be moved to achieve repeated dose escalations twice over 8 hrs, and responses to the first approach will be compared to subsequent approaches.

The operation is described in detail in the 3S-2023 cruise plan.

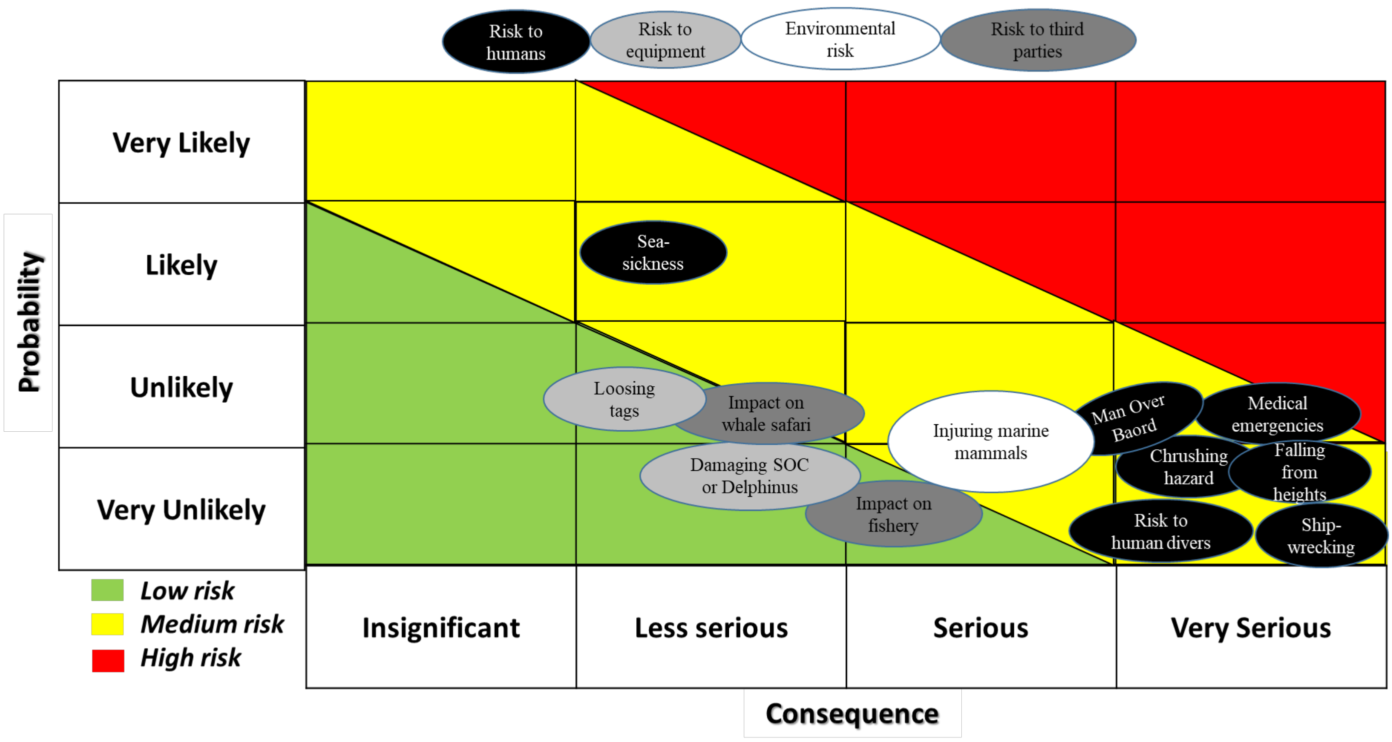

Figure 1. BLUF. Risk diagram summarizing the different risks associated with the 3S-2023 trial. Risks are categorized as low, medium or high based on the scored probability that the incident might happen and the consequence should it happen.

Risk inventory

The risk considered is risk to 3S staff involved in the trial on HUS, risk to third parties as a result of the 3S-2023 trial, risk to the environment, and risk of damaging or losing valuable equipment. Five types of risks are identified and mitigation measure and responsibility specified:

1) **Risk to the environment (injury to marine mammals)**
   Very Unlikely/Unlikely *x* Serious consequence = Medium risk

2) **Risk to third party human divers**
   Very Unlikely *x* Very serious consequence = Medium Risk

3) **Risk of impact on commercial activity (whale safari and fishery)**
   Very Unlikely/Unlikely *x* Less serious/Serious consequence = Low/Medium risk

4) **Risk of losing or damaging expensive equipment (Tags, Socrates and Delphinus)**
   Very Unlikely/Unlikely *x* Less Serious consequences = Low risk

5) **Risk to humans involved in the operation**
   Very Unlikely/Likely *x* Less Serious/Very serious consequence = Medium risk

1. Risk to the environment

During the planned 3S-2023 experiment we will use an active sonar system transmitting 1-2 kHz sonar signals at 214dB energy source level (re 1 $\mu Pa^2 \cdot s \cdot m^2$) in an area with high density of herring and marine mammals, particularly killer whales and humpback whales which are also our study subjects. Extensive research has been conducted to assess the risk of such naval sonar systems to the Norwegian marine environment (Nordlund and Kvadsheim 2021). The Norwegian Navy has implemented science based procedures to minimize risk to the environment (Andersen 2021), and are using an operational risk mitigation tool (SONATE) to plan sonar operations and comply with their procedures (Nordlund and Kvadsheim 2021). The 3S-2023 operation will follow these procedures to assure minimal risk to the environment, but with some carefully considered modifications to allow us to address the scientific objectives of the experiments.

Extensive research has shown that naval sonar has little or no effect on fish nor on fish populations (Sivle et al. 2014). With the exception of clupeid fishes like herring, fish can generally not hear sounds in the 1-2kHz band and are therefore not affected by it. There are high densities of herring in the study area, but previous studies specifically looking at the impact of 1-2kHz sonar signals on overwintering herring (Doksæter et al. 2009) have concluded that there is no risk of any population level impact (Sivle et al. 2014).

The objective of the study is to investigate behavioural responses of cetaceans to the transmitted sonar signals. Some level of disturbance should therefore be expected and accepted. The Norwegian Animal Research Authority has reviewed the experimental protocol and permitted the 3S-2023 experiments as described in the project description. They classify the impact on the experimental animals as mild. The experimental procedures have also been reviewed and approved by the University of St Andrews Animal Welfare and Ethics Committee. As part of the permitting process criteria for human end points, monitoring requirements and mitigation measures have been established. The study populations, North East Atlantic humpback whales and North East Atlantic killer whales, are not considered threatened or endangered by IUCN nor the Norwegian Artsdatabanken.

To predict the potential impact on the hearing of experimental subjects (killer whales and humpback whales) and other non-focal marine mammals in the area during our exposure experiments, we estimated the cumulative sound exposure level over the full 8hr experimental cycle (Table 1). The assumption for these estimates are that focal animals will be exposed during the entire exposure session but never closer than the 1000 m planned closest point of approach, whereas non-focal animals will be exposed only shortly, but never closer than a 100m stand off range. These simulations show that as long as the 100m shut down range is maintained, the exposure levels will be significantly lower than the threshold of hearing injury (PTS) for focal and non-focal animals. Focal humpback whales are exposed to levels close to their TTS-threshold, and could experience some temporary hearing loss, which they are expected to recover from within minutes if it did occur.

Table 1. Estimated weighted sound exposure levels (SEL) for focal animals (humpback whales and killer whales) and non-focal animals compared to the temporary hearing shift (TTS) and permanent hearing shift (PTS) criteria of Southall et al. (2019). The SEL estimates are based on simulations of ship movement, animal behavior and sound propagation. The assumption is a 1000m closest point of approach for focal animals and a 100m shut down range of the sonar for all marine mammals.

Marine mammals	**Weighted SEL_{cum} dB re 1 μPa²·s**	**Southall et al. (2019) threshold criteria**	
		PTS dB re 1 μPa²·s	**TTS dB re 1 μPa²·s**
Focal humpback whales	$SEL_{cum\text{-}8hrs}$ = 178 dB	199 dB	179 dB
Focal killer whales	$SEL_{cum\text{-}8hrs}$ = 153 dB	198 dB	178 dB
Non-focal LF ceteceans	$SEL_{cum\text{-}20s}$ = 174 dB	199 dB	179 dB
Non-focal HF cetaceans	$SEL_{cum\text{-}20s}$ = 149 dB	198 dB	178 dB
Non-focal VHF cetaceans	$SEL_{cum\text{-}20s}$ = 144 dB	173 dB	153 dB
Non-focal seals	$SEL_{cum\text{-}20s}$ = 174 dB	201 dB	181 dB

Risk mitigation measures

- Sonar transmissions will start with a 5min ramp up (gradual increase of source level) to reduce risk to marine mammals in the area by giving them time to move away. The ramp up procedure is specified in the cruise plan.
- A 500m mitigation action zone will be monitored by marine mammal observers on the source vessel during sonar transmissions. During transmission in the dark the observers will be equipped with thermal binoculars. If any mammals appear within 100 m from the source, the source will immediately be shut down. The source might be switched back on as soon as the animals are out of the danger zone.
- Sonar exposure experiments will be terminated if marine mammals show signs of distress, disorientation or extreme responses, such as consecutive breaching behavior, and also if the animals swim dangerously close to the shore or enter confined areas that will strongly limit their escape routes.

Responsibility

Permit compliance and management of environmental risk is ultimately the responsibility of the permit holder Petter Kvadsheim at FFI. In addition to Kvadsheim, Patrick Miller and Frans-Peter Lam (PI, CO and XO on HUS) will be field operators responsible for environmental risk and permit compliance in the field.

2. *Risk to third party human divers*

We will primarily operate off shore and in deep water and therefore don't expect to encounter human divers. However, some whale watching operators allow snorkelling or scuba diving with whales. Human divers are a marine mammal and can be injured by exposure to high levels of acoustic energy. The main concern with exposure of scuba divers is however, that divers might experience a high stress level during the exposure because they are unacquainted with the sonar sounds. The risk of such stress is much lower for free diving snorkelers. NATO guidelines (NATO 2006) differentiate between risk to naval divers and commercial and recreational divers. The guidelines are based on psychological aversion testing, and for commercial and recreational divers a maximum received sound pressure level (SPL) of 154 dB re 1µPa is established for the relevant frequency band. Based on the maximum source level of 214 dB re 1µPa·m and the maximum received sound pressure level of 154 dB re 1µPa and expected propagation conditions during the trial (18logR), the stand-off range from divers will be 4km for the source vessel HUS. This number includes a factor 2 safety margin.

Risk mitigation measures

- We will stay away from known diving sites.
- During sonar transmission there will be visual observers on the source boat. Any observed diving activity should be reported to the CO/XO on watch instantly, if any diver comes within 4km the transmission will be stopped.
- The 3S-2023 operation does not involve any diving activity by our own crew.

Responsibility

Management of risk to human divers is the shared responsibility of the navigation officers on watch on HUS and the commanding officers on watch. For HUS this means cruise leader/CO Kvadsheim or co-cruise leader/XO Lam.

3. Risk of impact on commercial activity (fishery, whale safari and whaling)

Research has shown that naval sonar has little or no impact on fish populations (Sivle et al. 2014). However, in the area closest to a sonar source, it is still uncertain if some fish species might respond to sonar transmissions. Such short-duration responses are unlikely to affect the vital rates of the fish, but might affect fishery catch rates. Safety distances known to not trigger any escape responses in fish are therefore established to avoid negative impact on fishery. Such safety distances will vary with the transmitted source level, duty cycle and speed of the source (Sivle et al. 2014). Fish in fish farms might be stressed by a sonar source passing closer than the safety distance, but the duration of this stress response will be very short, and is primarily triggered by the ship not the sonar.

The study species are two cetaceans previously shown to avoid the sonar source and cease foraging during exposure, and either to rapidly resume foraging (humpback whales; Sivle et al. 2016) or to have more prolonged responses (killer whales; Miller et al. 2014). Thus, sonar transmissions in an area can result in avoidance responses in marine mammals (e.g. Miller et al. 2014), and they might leave the area at least during the sonar operations (Kuningas et al. 2013). The threshold for avoidance will vary between different species (Harris et al. 2015) and it will also vary within a species depending on the behavioral context of the animals (e.g. are they feeding, migrating, socializing or breeding) (Sivle et al. 2015). Commercial activity related to marine mammals (whaling and whale watching), can therefore be negatively affected by naval sonar activity in the same area.

There is no commercial whaling going on in the operation area at this time of year. Whale watching are also unlikely in the off-shore areas, but if we operate in the more in-shore areas of Kvænangen we might encounter commercial whale watching operators bringing tourists out to watch our study species. We will primarily operate in the in-shore areas when the weather is too bad to work off-shore, and under such conditions whale watching boats might not be out. If there is whale watching activity going on, we will not conduct full duration exposure experiments in-shore until we have tested to which extent our experiments might lead to avoidance of the exposed area by whales over an extended period. In any case we will try to avoid doing behavioural studies in areas with dense vessel traffic close to the focal whales, because of the risk that this might compromises the controlled sonar exposure experiments.

Risk mitigation measures

- Prior to the operation we will contact the whale watching companies operating in the area and fishery organisations to inform them about our planned activity.
- During active transmissions by the Socrates source, a safety distance (sonar shut down range) of 500m from fishing vessels actively engaged in fishing will be maintained.
- During the operation we will monitor where the whale watching vessels primarily operate and as much as possible stay away from their core area.
- To minimize risk of accumulated effects of active sonar transmissions will not be conducting experiments closer than 20 nmi of where HUS conducted previous exposures experiment within 48 hours. This is also important to avoid habituation or sensitization of the experimental animals.

Responsibility
Management of risk of impact on commercial activities is the ultimate responsibility of FFI operating the research vessel HUS. On a daily basis the responsibility to manage this risk lay with the CO on HUS Petter Kvadsheim and the XO in his absence (Lam).

4. *Risk of losing or damaging expensive equipment (Tags, Socrates and Delphinus)*

During the operation both the SOCRATES source and the DELPHINUS array will be deployed and towed by the Sverdrup. SOCRATES is a multi-purpose sophisticated versatile towed source that is developed by TNO for performing underwater acoustic research. The Delphinus array is a single line array, 74 meters long used to detect and track whales. Risk of damage to these systems includes risk of hitting the sea floor, risk of cavitation during high power transmission and risk of entanglement while towing both systems simultaneously (dual tow). A separate chapter of the cruise plan contains specifications of the equipment as well as procedures for safe deployment, operation and recovery.

During operation we will deploy sophisticated digital tags (DTAG3 or Mixed DTAG+(+) to whales, expecting to recover them 24-30hrs later. The intended use of the tags are specified in the 3S-2023 cruise plan. The tags are not commercially available and are especially made by University of Michigan and who makes then available to marine mammal research projects. If we lose tags, we lose data and other research groups might have to do with fewer tags. The current version of the tags have two transmitter types (VHF and Argos) enabling us to recover them using appropriate antennae systems and this reduces the risk significantly. The risk of losing tags are mitigated by careful testing beforehand, checking that batteries and sensor work as attended and double checking that the tags are programmed properly before deployment. Tags placement is also critical to optimize the chance that we can track the tag while on the whale.

Risk mitigation measures

- Risk mitigation measures for deployment, operation and recovery of the Socrates and Delphinus system are specified in the 3S-2023 cruise plan.
- Procedures for deployment of tags are specified in the 3S-2023 cruise plan.

Responsibility
Management of risk of damaging Socrates and Delphinus is the ultimate responsibility of chief scientist of the TNO team Frans-Peter Lam. However, the captain of the ship, his first officer, and the cruise leader Kvadsheim are responsible for assuring that the equipment is used in accordance with the

instruction given by TNO. The responsibility of managing risk of tag loss lies with the PI prof Miller.

5. Risk to humans involved in the operation

Being on a ship at high sea constitute some elevated level of risk (e.g. tripping, falling over board, crushing hazard etc). The research vessel HU Sverdrup II is certified according to the ISM-code (International Safety Management) approved by IMO (International Maritime Organisation). This is a comprehensive safety regime to minimize risk of accidents. An instruction to the scientific crew during the trial summarizes the safety regime, and responsibilities. Certain types of work operations, like working on tag boats, climbing in masts, or deployment and recovery of equipment from the aft deck require a work permit from the safety officer on the bridge. Before such a permit is issued a safety toolbox talk is required to clarify tasks, responsibilities, communication and necessary safety equipment for the people involved.

The ship will operate off-shore and getting acute medical care in an emergency will take longer than usual. During the 3S-2023 trial we will still operate within helicopter range for the search and rescue service. It is still considered critical that all personnel on board, including the science staff, are at good health and have basic first aid training before departure.

There is also a theoretical chance of fire or water intrusion making a full evacuation of the ship necessary. In such an emergency it is critical that everyone can take care of themselves as much as possible and therefore basic safety training with life rafts and survival suits are necessary. The scientific staff do not have formal safety roles on board, but it could take time before we get external help, and in emergencies we should be prepared to assist the ship's crew.

Risk mitigation measures

Table 2. Risk mitigation action plan for human risks during the 3S.2023 trial. Each theoretical incident is described with probability, consequence and necessary risk mitigation measures.

Incident	Probability	Consequence	Risk mitigation
Man Over Board in cold arctic ocean could lead to hypothermia or drowning	Unlikely	Serious/Very Serious	Use of personal flotation device when working on open aft deck. Use of floatation suit in tag boats. Safety toolbox talk and safety training of deployment and recovery of tag boats for tag boat crew.
Crushing hazard when working in tag boats or on aft deck with cranes	Very unlikely	Very Serious	Safety toolbox talk before deployment of tag boats or heavy equipment from aft deck. Wear helmet and safety shoes in tag boats and on deck. Training of deployment and recovery of tag boats for tag boat crew.
Falling from heights during placements of antennae	Very Unlikely	Very Serious	Safety toolbox talk before any work >2m above the deck. Use safety harness when climbing
Medical emergencies far away from hospital could be life threatening	Very unlikely	Very Serious	First aid training of crew Medical check before departure
Shipwrecking due to fire or sinking	Very unlikely	Very serious	Safety brief on board before departure, safety training course also for science crew before embarkment
Sea sickness in rough seas	Likely	Less serious	Sea sickness medication.

For the 3S-2023 trial the following operations requires special attention:

- During deployment/recovery of Socrates all personnel involved in the operation on the aft deck should wear helmet, life vest and steel toe shoes. Support ropes will be used to prevent the hoisted equipment (Socrates) from swinging during ship movements. Personnel who operate winches, cranes, A-frame etc must take care and keep other personnel out of the way.
- Any personnel who are going in the work boats (Tag boats) should be briefed on how to operate the hooks, and the deployment and recovery procedure should be exercised in calm water. Personnel should wear floatation suits at all times during operation in the work boats. Personnel in the work boats should wear helmets during deployment and recovery. Work boats should not operate more than 4nmi from the mother ship and always within VHF range. Work boats must report in to Sverdrup to confirm communication lines every hour. Use of work boats is limited to sea states 4 and below.

Responsibility

The shipping company (FFI) and the ship's contracted operator (Remøys shipping) are responsible for implementation of the safety regime. The ship's captain, and in his absence the first officer, is the chief authority with regards to safety of all personnel. He is responsible for the comprehension and complying of all safety instructions. The party chief (cruise leader Kvadshiem) is responsible for making current instructions known to and comprehended by the survey participants and the crew. All scientific staff should read and understand the "Instructions to survey personnel on board "HU Sverdrup II".

Other relevant documents

3S-2023 cruise plan
Specifications, deployment, operation and recovery of SOCRATES and DELPHINUS systems
Report on Test of Pulsar Merger thermal imaging binoculars LRF XP50
NARA permit 23/110085
Instructions to survey personnel on board HU Sverdrup II

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E Report on Test of Pulsar Merger thermal imaging binoculars

Marine mammal monitoring in the dark – Test of Pulsar Merger thermal imaging binoculars LRF XP50

Prepared for DRDC

March, 2023

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Marine mammal monitoring in the dark – Test of Pulsar Merger thermal imaging binoculars LRF XP50

13 March 2023

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This stydy was conducted as part of the 3S4-project

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Executive Summary

The 3S4-2023 survey is planned to take place during October—November in the Arctic Norwegian Sea. The 3S4 field study, is expected to include controlled sonar exposure experiments to tagged cetaceans, with some experiments taking place during periods of darkness. This report describes the testing of the night vision Pulsar Merger LRF XP50 to detect nearby cetaceans during darkness. Primary targets were killer whales and humpback whales, with the goal of evaluating whether this thermal binocular is suited and functional to detect marine mammals in the darkest night (**Error! Reference source not found.**). The specific objectives were to test the feasibility of doing effective mitigation monitoring within 500 m range using Pulsar Merger LRF XP50 and to identify which equipment settings to use. The tests were performed north of Tromsø in the fjord of Kvænangen in January 2023 in full darkness. Killer whales and humpback whales were clearly visible out to >1,000 m range in realistic sea conditions (up to Beaufort 3). Thus, the Pulsar Merger XP50 will function well for nighttime mitigation during the planned 3S4 trials. Based on these tests the red monochrome colour mode with the smallest magnification is recommended during marine mammal risk mitigation monitoring. Real time use of the Pulsar Merger LRF XP50 performs better than the presented pictures in the body of this report which were print screened from video clips.

Figure 1. Test of Pulsar Merger LRF XP50 in total darkness. In the left panel humpback whales are visible at 300m, while in the right panel humpback whale tail and a killer whale are visible at 300m, both by using Ultra marine colour mode.

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1 Introduction

During active sonar experimentation and testing, monitoring of an area (commonly referred to as the Mitigation Action Zone, or MAZ) around the sonar source vessel for the presence of cetaceans is required to reduce the risk that unintended physical harm might be caused by the active sonar transmissions. A typical range for the MAZ for military sonar systems is 500 m. Common methods for monitoring the MAZ are visual and passive acoustic monitoring. Visual monitoring is normally limited by weather conditions and to daytime hours.

This project sought to test night-time visual monitoring methods; in particular, the use of thermal binoculars. The goal was to determine whether thermal binoculars are a reliable a mitigation tool, within a typical MAZ range, for sonar testing during night-time when standard visual monitoring is not possible. This is particularly important for acoustics experimentation and sonar training during long Arctic nights and would increase the working time available if found to be effective.

2 Methods

The Pulsar Merger (**Error! Reference source not found.**) was tested at sea during commercial herring fisheries in the dark north of Norway in the fjord of Kvænangen in January 2023. The weather was good with mostly light to gentle breezes from various directions and minus 2-4 degree Celsius. The Pulsar Merger unit comes with an internal (1) and one external (2) battery and at minus 3 degrees Celsius and fully charged can function for 4 + 3,5 hours, for a total of 7.5 h under these conditions. This was tested outdoors during the day, without any video/audio recording. The LRF XP50 is waterproof (IPX7) and robust, appearing like standard binoculars, with a weight of 1000g, 6 functional buttons well operated by 3 plus 3 fingers on each hand. The video function is good with excellent audio recording. Maximum recording duration on a given file is 5 minutes, and the system will continue recording on a new file if needed. A total of 59 recordings were made during 3 nights. Many of these were testing files trying out different setups to optimize the contrast to the animals (killer whales and humpback whales) relative the ocean, adjusting for colouration, brightness and contrast. The tests were performed around boats during herring fisheries at night.

Figure 2. The Pulsar Merger thermal imaging binoculars LRF XP50.

[Manuals | Pulsar (pulsar-nv.com)]

3 Results

The rangefinder tool was functional out to 1,000 m, however functionality was considered practical on humpback whales out to 300 m and on large orcas out to 150 m on good weather conditions like we had during these nights (Table 1). During the fisheries we had both humpback whales and orcas around the fishing vessels so we could measure range to the boats when ranging on the whales was not possible at larger distances (**Error! Reference source not found.**, Figure 4, Figure 5, Figure 6). Recordings were made with vocal descriptions at 150, 300 and 500m, experimenting with the colouration, as well as a setup starting 500m from one active fishing boat (Figure 7) with orcas at various ranges, passing the fishing boat 100 meters rear of the boat at 8 knots, to 500 meters at the other side of the fishing boat. Real time use of the Pulsar Merger LRF XP50 performed better than the presented pictures below which were print screened from video clips.

Figure 3. Test of Pulsar Merger LRF XP50 in total darkness. In the left panel a killer whale at 40 m by using black hot colour mode, while in the right panel killer whales at 40 m by using ultramarine colour mode.

Figure 4. Test of Pulsar Merger LRF XP50 in total darkness. In the left panel killer whales at 150 m by using black hot colour mode, middle panel killer whales at 150m by using ultramarine colour mode, and in the left panel killer whale at 150 m by using white hot colour mode.

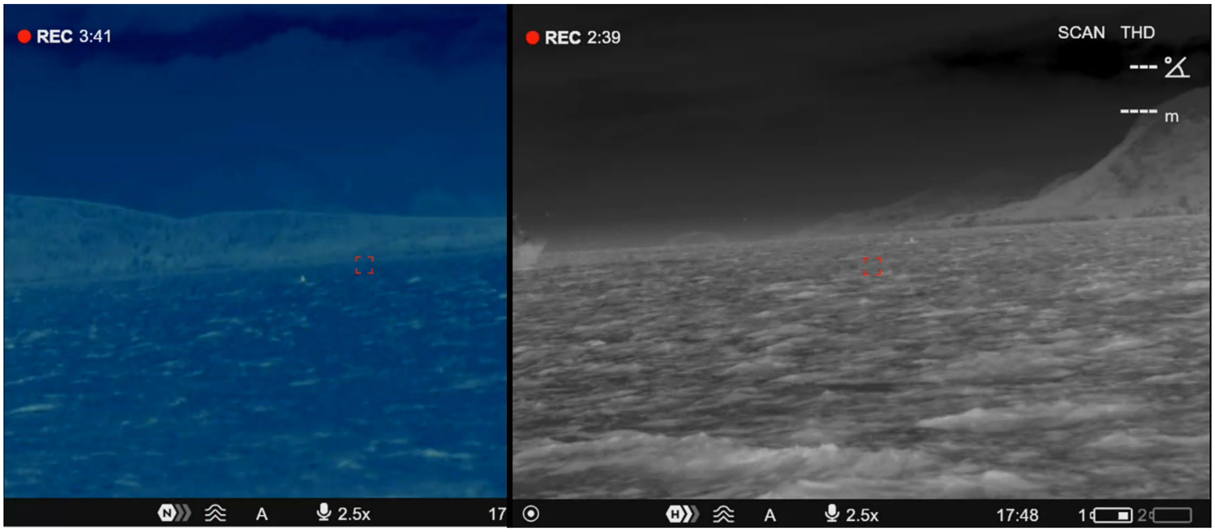


Figure 5. Test of Pulsar Merger LRF XP50 in total darkness. In the left panel a killer whale at 700 m by using ultramarine colour mode, while in the right panel a killer whale at 700 m by using white hot colour mode.

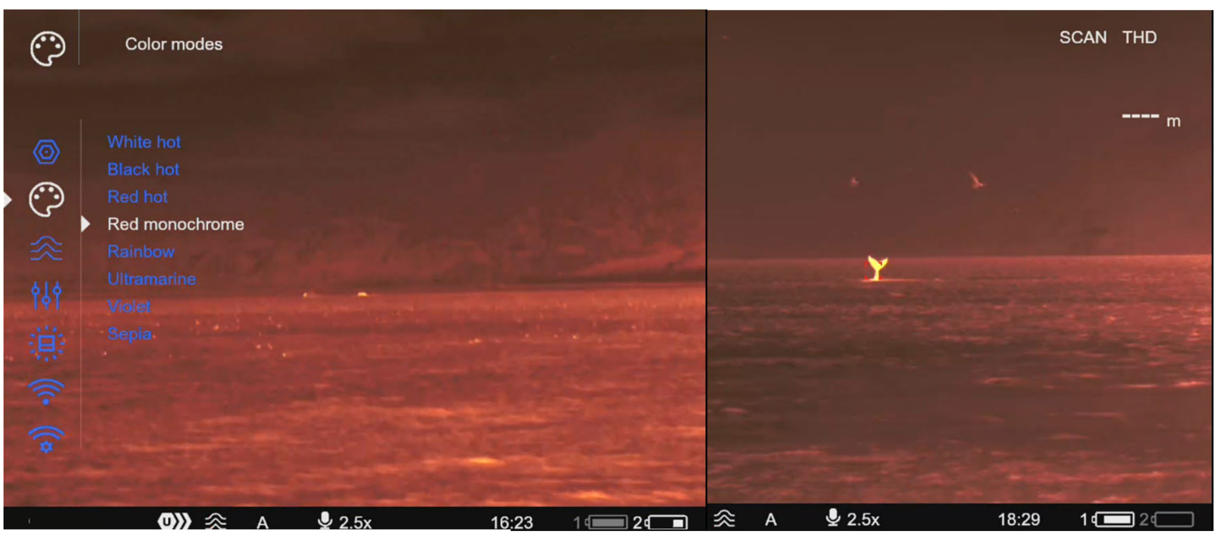


Figure 6. Test of Pulsar Merger LRF XP50 in total darkness. In the left panel humpback whales at 1,600 m by using red monochrome colour mode, while in the right panel a humpback whale tail at 1,000 m by using red monochrome colour mode.

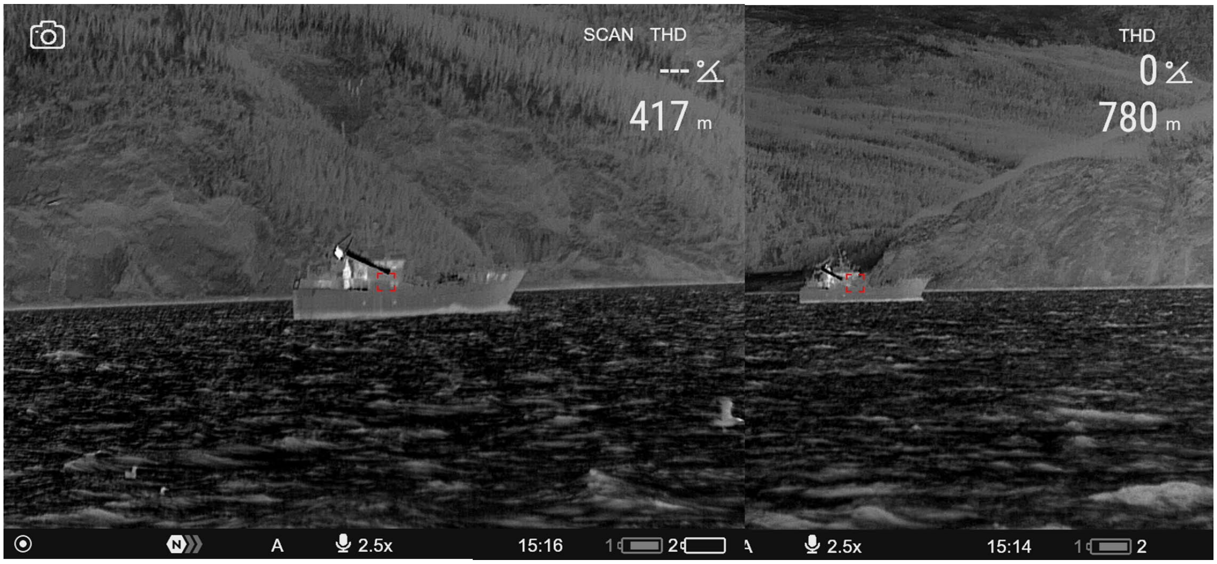


Figure 7. Test of Pulsar Merger LRF XP50 in total darkness. Fishing boats at different distances, in the left panel at 417 m and in the right panel at 780 m, both using white hot colour mode.

Table 1 Marine mammal detections using Pulsar Merger 14-16 January 2023 North of Norway, Reisafjorden 6993N-2113N and Skorpa 6995N-2165E.

The table below assimilates video/audio recordings during tests of the Pulsar Merger LRF XP50 in total darkness, around herring fishing vessels targeting killer whales, humpback whales and fishing boats. Fishing boats were often used to calibrate for range on the range finder unit of the Pulsar binoculars. Cues visible with system: Orca -body (blow) Humpback whale – body and blow. The best performance configuration of the Pulsar Merger was: Lowest digital optical zoom of 2.5x, Colour mode Red Monochrome with Amplification level (U), Lighting at 20, Contrast at 15 and Calibration mode at Auto.

Date	Time	Beaufort	Species:	Group size:	Distance: Meter	RF or Eye**	Visible***	Video	Comments (e.g. colour modes of unit which part of whale or blow is most visible)
14/01/23	15:32	3	Orca	10	1300	Eye	Good+	049	White Hot (N), Body
14/01/23	15:35	3	Orca	10/3	700/1400	Eye/Eye	Good	049	Ultramarine (N), Body
14/01/23	16:19	3	Orca	5/2	400/800	Eye/Eye	Good	049	Ultramarine (N), Body and blow
14/01/23	16:23	3	Orca	3	50/100	RF	Good	050	Ultramarine (N), Body
14/01/23	16:42	3	Boat	1	969	RF	Good	051	Ultramarine (N), Boat
14/01/23	16:43	3	Humpback	2	231/131	RF	Good	051	Ultramarine (N), Body and blow
14/01/23	16:47	3	Boat	1	384	RF	Good	051	Ultramarine (N), Boat
14/01/23	16:49	3	Humpback	2	500	Eye	Good	051	Ultramarine (N), Blow
14/01/23	16:55	3	Orca	8	115/159	RF	Good	053	Ultramarine (N), Body
14/01/23	17:00	3	Orca	1/1	82/149	RF	Good	053	Ultramarine (N), Body and blow
14/01/23	17:01	3	Boat/Orca	1/3/4	657/600/600	RF/RF/Eyerf	Good	054	Ultramarine (N), Body
14/01/23	17:14	3	Boat/Orca	1/3	376/69	RF/RF	Good	054	Ultramarine (N), Body
14/01/23	17:17	2	Boat/Oo/Mn	1/8/1	298/300/300	RF/Eyerf/Eyerf	Good	058	Ultramarine (N), Body and blow
14/01/23	17:19	2	Humpback	2	97	RF	Good	059	Ultramarine (N), Body and blow
14/01/23	17:21	2	Boat/Orca	1/1	267/270	RF/Eyerf	Good	060	Ultramarine (N), Body

14/01/23	17:29	2	Boat/Orca	¼	276/280	RF/Eyerf	Good	064	Ultramarine (N), Body
14/01/23	17:39	2	Boat/Orca	1/5/5	201/200/300	RF/Eyerf/Eyerf	Good+	065	White Hot (N), Body
14/01/23	17:42	2	Orca	3	69/90	RF/RF	Good+	066	White Hot (N), Body and body
14/01/23	17:46	3	Boat/Orca	1/3/3	618/600/600	RF/Eyerf/Eyerf	Good+	068	White Hot (N), Body and body
14/01/23	17:52	3	Boat/Orca	1/3/2	606/700/600	RF/Eye/Eye	Good+	068	Ultramarine (H), Body and blow
14/01/23	18:02	3	Orca	3	100	RF	Good+	072	Ultramarine (H), Body and blow
14/01/23	18:06	3	Orca	6	39	RF	Good+	073	Ultramarine (H), Body and blow
14/01/23	18:10	3	Orca	2	91	RF	Good+	075	Ultramarine (H), Body and blow
14/01/23	18:31	3	Boat/Orca	1/5	307/300	RF/Eyerf	Good+	076	Ultramarine (H), Body and blow
14/01/23	18:33	3	Boat/Orca	1/5	186/190	RF/Eyerf	Good+	076	Ultramarine (H), Body and blow
14/01/23	18:39	3	Boat/Orca	1/10	76/150	RF/Eye	Good	077	Ultramarine (H), Body and blow
14/01/23	22:45	3	Boat/Orca	1/7	207/200	RF/Eyerf	Good	081	Ultramarine (N), Body
14/01/23	22:47	3	Boat/Orca	1/10	180/180	Eye/Eyerf	Good+	081	Ultramarine (H), Body
14/01/23	22:48	3	Boat/Orca	1/10	180/180	Eye/Eyerf	Good+	081	Ultramarine (U), Body
14/01/23	22:50	3	Boat/Orca	1/20	288/150/300	RF/Eyerf/Eyerf	Good	081	Ultramarine (N), Body
14/01/23	22:54	3	Boat/Orca	1/10	164/100/300	RF/Eyerf/Eyerf	Medium	082	Black Hot (N), Body
14/01/23	22:57	3	Boat/Orca	1/7	194/270	RF/Eyerf	Medium	083	Black Hot (N), Body
14/01/23	23:02	3	Orca	1	75	RF	Good	084	White Hot (H), Body
14/01/23	23:06	3	Boat/Orca	1/3/3	126/70/200	RF/Eyerf/Eyerf	Good	085	Black Hot (U), Body
14/01/23	23:09	3	Boat/Orca	1/5/3	113/70/150	RF/Eyerf/Eyerf	Good	086	Black Hot (U), Body
14/01/23	23:11	3	Boat/Orca	1/3/3	104/100/300	RF/Eyerf/Eyerf	Good	086	Ultramarine (N), Body
14/01/23	23:38	3	Boat/Orca	1/3	90/120	RF/Eyerf	Good	089	Black Hot (U), Body
15/01/23	16:08	2/3	Orca	1/3/4	115/100/30	RF/RF/RF	Medium	095	Black Hot (U), Body, Digital

									dust!!*
15/01/23	16:13	2/3	Boat/Oo/Mn	1/5/1	151/100/100	RF/Eyerf/Eyerf	Medium	096	Black Hot (H), Body, Digital dust!!*
15/01/23	16:25	2/3	Boat/Oo/Mn	1/6/1	307/300/300	RF/Eyerf/Eyerf	Medium	097	Black Hot (H), Body*
15/01/23	16:50	3	Oo/Mn	1/3	77/150	RF/Eyerf	Medium	098	Black Hot (H), Body and Blow*
15/01/23	16:51	3	Boat/Oo	1/10	131/150	RF/Eyerf	Medium	099	Black Hot (H), Body*
16/01/23	16:18	2	Humpback	4	2500	Eye	Good	127	Black Hot (U), Body and Blow
16/01/23	16:25	2	Humpback	4	2500	Eye	Good++	128	Red Monochrome (U), Body and Blow
16/01/23	16:30	2	Boat	1	664	RF	Good++	129	Red Monochrome (U)
16/01/23	16:41	2	Humpback	2	1000	Eye	Good++	131	Red Monochrome (U), Body and Blow
16/01/23	18:19	2	Boat/Mn	1/1	242/230	RF/Eyerf	Good++	141	Red Monochrome (U), Body and Blow
16/01/23	18:22	2	Humpback	1	55	RF	Good++	141	Red Monochrome (U), Body and Blow
16/01/23	18:29	2	Humpback	1	500	Eye	Good++	142	Red Monochrome (U), Tail
16/01/23	18:30	2	Humpback	1	500	Eye	Good++	143	Red Monochrome (U), Body, Blow and Tail

* *Digital dust if calibration mode is at manual, then a need of action, however avoided by using Automatic*

** *RF – range finder reference, Eye – no range finder reference, Eyerf –close to a range finder reference- a fishing boat*

*** *Personal judgments for the best contrast between whale body and the ocean, where Good++ is the best outcome.*

4 Discussion

The final and most effective setup ended with minimum magnification at 2.5x, red monochrome colour mode, contrast at 15 and brightness at 20. With this setup under weather conditions at Beaufort 3 or better, the control of a sector out to 1,000 meters would be operational to sight both humpback whales and orcas. The animals would appear white, and the blows are also visible for humpback whales and larger killer whales. On the last night under very calm weather conditions, humpback whale blows and body were also clear at 2,000 meters. However, under rough weather the range would be reduced. The Pulsar Merger LRF XP50 performs better and sharper in real-time than video recordings and pictures selected from the video clips (Figure 8).

For longer watches a binocular stick should be mounted on the unit to improve the working position and thus operator performance. The LRF XP50 has a tripod connector where this should be possible. Since the range finder is not optimal on smaller targets at greater ranges, it would be good to make some tests from the upper-bridge of HU Sverdrup to adjust for the height with a reference to the horizontal water line and a target like Mobhus at different distances.

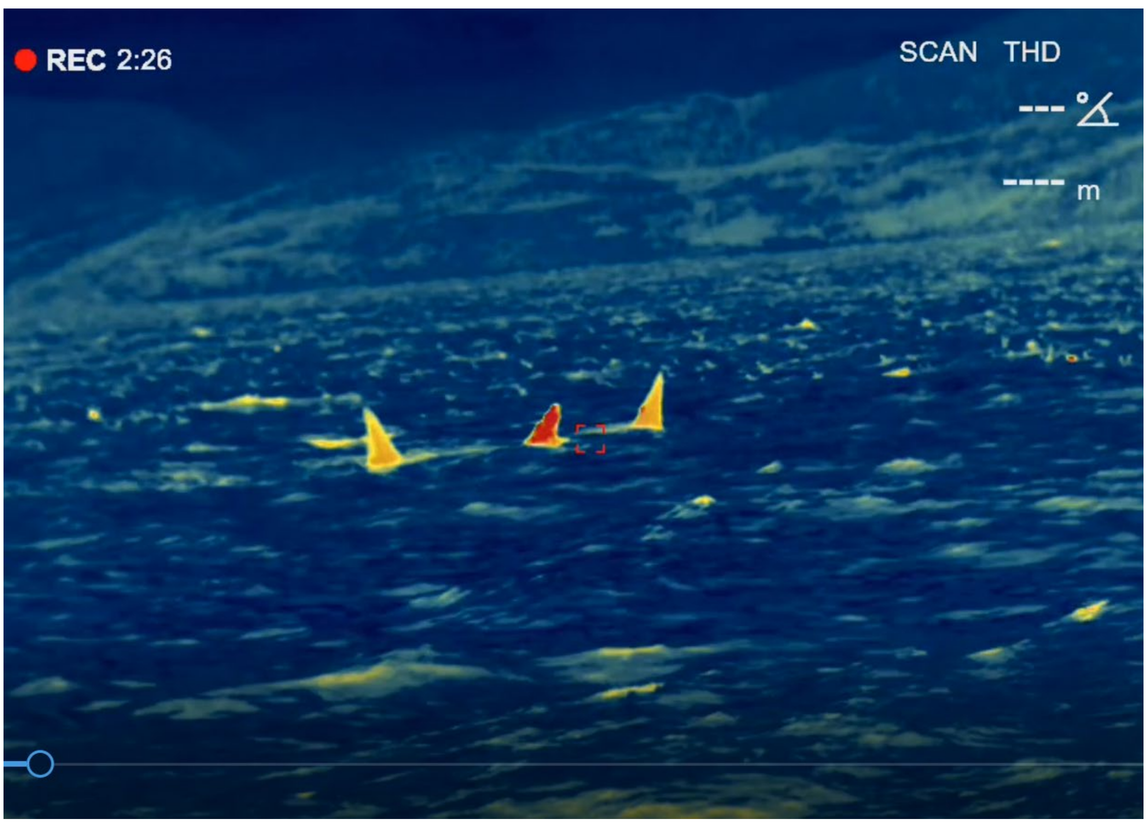


Figure 8. Test of Pulsar Merger LRF XP50 in total darkness. Killer whales at 80m by using ultramarine colour mode.

5 Acknowledgements

This study was funded by the Defence Research and Development Canada. It was initiated by the Sea Mammals and Sonar Safety (3S4) project who plan to do controlled exposure experiments on killer whales and humpback whales, where part of the exposure period will be in the dark. They have a need to establish reliable monitoring of marine mammals within the permitted mitigation action zone. Patrick Miller (SMRU) and Petter Kvadsheim (FFI) from the 3S project are acknowledged for their contribution to this study. Many thanks to Rune Landrø at Magne Landrø AS for providing us with the Pulsar Merger LRF XP50 in time for this test, and to Jørgen Ree Wiig and his colleagues at the Norwegian Directorate of Fisheries for their support at sea.

F 3S-2023 Pilot study cruise report

Cruise Report
3S-2023 - Iceland Pilot study Trial

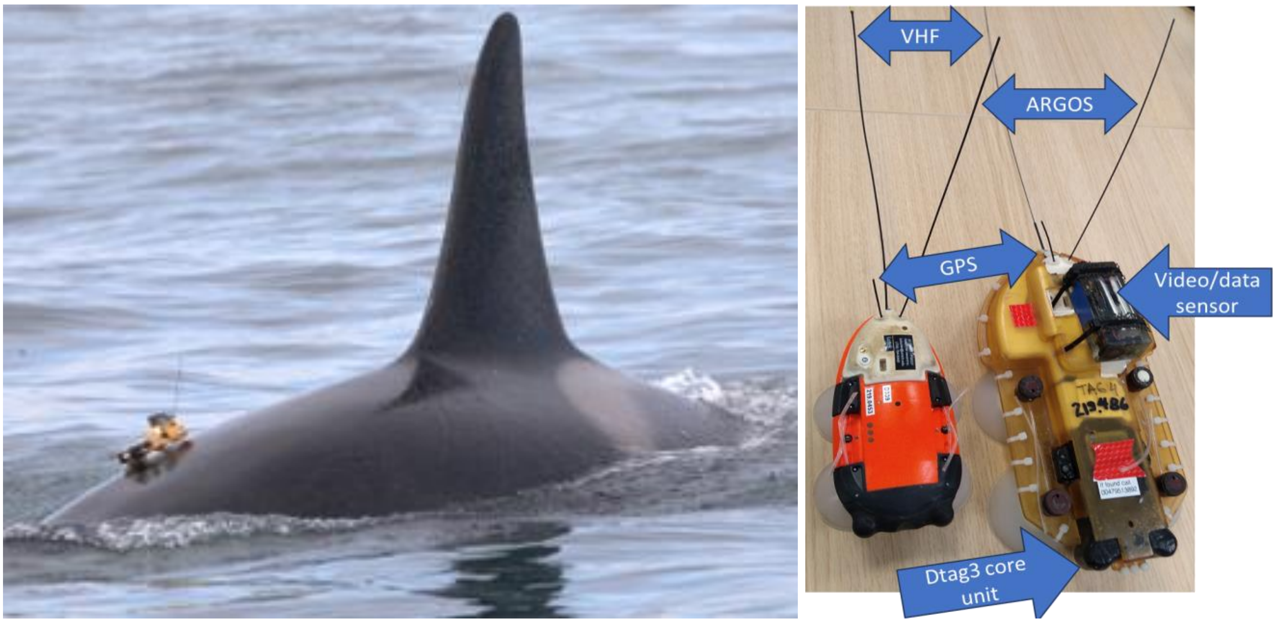


Figure 1: Left panel shows Mixed-DTAG++ deployment oo23_181b. This deployment stayed attached to the whale for 24 hrs, and proved to be the ideal placement for successful goniometer reception of GPS locations. Photo by Anna Selbmann. Right panel shows the two tag types used in trial, integrated-DTAG on the left and Mixed-Dtag++ on the right. Note that the two tag types use the same LOTEK F6G134A FastGPS ARGOS system. The mixed-DTAG++ includes a DTAG3 core unit, and a Little Leonardo DVLW2000M130SW-4R video and data logger.

23 June -21 July, 2023

Patrick Miller, Cruise Leader; Filipa Samarra, Field Party Chief

Cruise Report prepared by:
Patrick Miller, Filipa Samarra

The 2023 Pilot Study trial in Iceland was funded by US LMR (project 57) and French DGA as part of the 3S research collaboration. Additional funding was provided by Rannís, Earthwatch Institute and the Jules Verne Foundation. Fieldwork was conducted under a Marine and Freshwater Research Institute (Hafrannsóknastofnun) institutional permit, and research protocols were approved by the U of St Andrews Animal Welfare and Ethics Committee.

TRIAL OUTCOME – EXECUTIVE SUMMARY

Overall, the 3S-2023 pilot study cruise in Iceland (23 June – 21 July, 2023) was highly successful. As in 2021 and 2022, all facilities and equipment worked well – weather and whale conditions were favourable. All Primary and Secondary Tasks were accomplished.

The field effort was conducted from 23 June – 21 July 2023. From 28 total days of effort, 5 days were used for setup, breakdown and logistics. Of the remaining 23 days, we had workable weather on 13 days, >50% and slightly exceeding our expectation. Of the 13 days, whales were found on most days and suction-cup tags (Mixed-Dtag++ or integrated DTAGs, Fig. 1) were attached on 7 days. A total of 14 tags were deployed, 8 to killer whales, 2 to humpback whales and 4 tags were deployed on long-finned pilot whales. Mixed-Dtag deployments (N=7) on killer and humpback whales had good retention times, with an average duration of 15.9 hrs, and a maximum deployment duration of 24.8 hrs. Integrated Dtag deployments (N=3) on killer and humpback whales had shorter average retention of 8.4 hrs, and maximum of 13.5 hrs.

As in previous efforts, ARGOS locations were successfully received while tags were attached to animals, and while floating after attachment (except one case oo23_188b when the antennas appear to have been bent while attached to the whale – Table I), aiding tag recovery. Video and data recordings using newly produced Little Leonardo DVLW2000M130SW-4R video and data loggers were highly effective and data recordings were made consistently. The data recordings demonstrated how a separate dedicated unit can provide data (depth and acceleration) redundancy in case of core unit errors. The video recordings were high quality, revealing details of underwater behaviour, though the video start times did not always match the programmed start times.

On-animal location performance by both tag types was quantified carefully during the trial (Table I). We achieved a breakthrough in performance of GPS tracking using the Goniometer antenna. Successful locations were received from the Goniometer system for 4 of the 5 deployments – with no GPS positions obtained for a smaller animal tagged to the side of the dorsal fin. Reception rates for the 4 successful tags ranged from 8.5-17.7/hr with locations received at a rate of 7.7-13.0/hr. GPS positions were received with an average delay (time from GPS fix on animal to reception) of 7-16 minutes. Maximum ranges of successful receptions by whale were 3.5-5.9nm. GPS locations received via the goniometer were used to relocate animals on multiple occasions, and even to conduct playback experiment the day after tags were attached. This indicates GPS tracking with the Goniometer system can be relied upon to conduct experiments at sea, with careful tag placement. Though all successful goniometer tests were for mixed-DTAG++ deployments, we expect that similar performance should be obtained for integrated-DTAGs as identical FastGPS-ARGOS units provided by LOTEK are used for both tag types.

<u>Conclusions and Recommendations for the 3S4 sonar-effects study</u>

The 2023 pilot study demonstrated the readiness of the current version of the Mixed-DTAG++ for use in the 3S4 field trial planned for October-November 2023. At least half of the Mixed-DTAG retention times were long enough to conduct the full long-duration exposure protocols planned for 3S4.   Attachment durations were more reliable for tagged adults than juvenile animals. We demonstrated effective performance of on-animal GPS tracking, so long as tags were placed high on the body. GPS positions were received at distances (4-5nm) consistent with the distance-to-the-horizon for the Fridrik antenna height of 5m. If similar performance can be achieved on the HU Sverdrup II with higher antenna placements, we might receive regular successful GPS positions at 8-10nm distance from whales for tags placed high on the body.

Because tag placement is so critical, pole tagging is recommended for the 3S4 trial, with ARTS only as a secondary system when critically needed. We recommend to prioritize use of Mixed-Dtag++ units and focus on tagging adult animals (avoiding small animals) placing tags 1.) high on the body between the dorsal fin and blowhole (as in deployment oo23_181b) or 2) on the dorsal fin with antennas angled up (as in deployment oo23_188a). Use of a 90-degree attachment robot is recommended to place tags on the body between the dorsal fin and blow hole.

OPERATION AREA

The operation area was waters near the island of Heimaey in the Westmann Islands, Iceland.

OUTOMES VERSUS CRUISE TASKS

Below is a summary of the outcome of the cruise tasks. Primary tasks had a higher priority than the secondary tasks. We tried to accomplish as many of the secondary tasks as possible, but they were given a lower priority.

PRIMARY TASKS

Primary task 1. *quantify and improve the functionality of GPS-ARGOS linked Mixed-Dtag++ and integrated Dtag3 to provide locations of tagged cetaceans via a) the ARGOS satellite system, and b) Goniometer reception of signals. The rate of reception, and delay involved, will be quantified and incrementally improved by optimizing software settings and hardware characteristics. Tests will be carried out with the vessel in dock and at sea, focusing on the whale-antenna distances over which the signals can be successfully received and decoded using the Goniometer system. Tags will be attached with hand poles. The killer whale is the primary species, but long-finned pilot and humpback whales may also be tagged.*

OUTCOME: This task was accomplished successfully with tracking done using 2 different antenna systems on the Fridrik, as well as by the ARGOS satellite system. One set of boat-boat tests at the start of the trial demonstrated the reception system was functioning effectively to a distance of ~5nm. As in 2022, the custom +5dB antenna was found to be most effective to receive and decode GPS locations, while the -2dB standard Goniometer antenna was most effective at providing real-time bearing information for received signals.

In total, we tagged 14 whales (8 killer, 2 humpback and 4 long-finned pilot whales). Real-time Goniometer tracking from the Fridrik was attempted for 5 deployments (4 killer and 1 humpback whale). Successful locations were received from the Goniometer system for 4 of the 5 deployments. Reception rates for these 4 tags ranged from 8.5-17.7/hr with successful locations received at a rate of 7.7-13.0/hr. GPS positions were received with an average delay (time from GPS fix on animal to reception) of 7-16 minutes. Maximum ranges of successful receptions by whale were 3.5-5.9nm. No Goniometer locations were received during a deployment on a juvenile sized killer whale with the tag attached just below the dorsal fin. This result means that near real-time GPS tracking via Goniometer receptions can work reliably, particularly with adult-sized animals, but is dependent upon tag position on the body.

Primary task 2. *deploy the Mixed-Dtag+ with the new Little Leonardo video-data sensor. Test release times >24 hr to establish maximum suction cup retention times.*

OUTCOME: Newly purchased DVLW2000M130SW-4R Little Leonardo video-data sensors recorded successfully for all 9 deployments done using the mixed-Dtag++ (the integrated dtag did not include the video-data sensor). All deployments recorded high-quality video for 6-8 hours and high-quality depth and accelerometer data for 24 hours. Visual comparisons of the depth record confirmed a match with that recorded by the Dtag core units, demonstrating that the Little Leonardo units will be effective as a data backup system in case of core unit errors. Video quality was high, but video files did not always start recording at the expected time. Care will be needed to synchronize the videos with audio recorded by the DTAG core unit.

Mixed-Dtag deployments with killer and humpback whales (N=7) had good retention times, with an average duration of 15.9 hrs, and a maximum deployment duration of 24.8 hrs. Integrated Dtag deployments with killer and humpback whales (N=3) had substantially shorter average retention of 8.4 hrs, and maximum of 13.5 hrs. For killer whales, tag deployments were generally longer, and more likely to last until the scheduled release time, when the tagged animal was an adult sized animal or larger juvenile (e.g. oo23_181a, oo23_181b, oo23_188a) whereas deployments on smaller animals (oo23_184a, oo23_191a) tended to be shorter and less likely to last until the programmed release time.

Primary task 3. conduct playback experiments with natural sounds (e.g. long-finned pilot whale sounds) to tagged killer whales, aided by locations provided by the GPS-ARGOS system. This will validate the functionality of the new tag systems to perform in controlled exposure experiments planned for the full 3S4 study. Visual surface observations will be collected before, during and after playbacks.

OUTCOME: A total of five exposure sessions were successfully conducted during experiments with 3 different subjects. Four of the five exposure sessions were conducted the day after tagging and animals were successfully located and approached for visual tracking using the Goniometer reception systems. In both cases, bearings were received from the standard Goniometer antenna and GPS positions were received from the +5dB custom antenna. The result confirms the benefit of near real-time GPS positions received by the Goniometer for conducting experiments at sea.

SECONDARY TASK OUTCOMES

Secondary task 4

Collect sightings, photographs, and acoustic recordings of target species and other cetaceans encountered.

OUTCOME: Extensive sightings and photographs of the encountered animals were successfully obtained.

Secondary task 5. *Collect echosounder survey data of herring in the study area, using a SIMRAD EK-60 or EK-80 echosounder system.*

OUTCOME: A set of echosounder surveys were completed, which were conducted independently of the tagging efforts.

Secondary task 6. *Collect biopsy samples of whales in the study area*

OUTCOME: This was not done by the 3S project team, as their focus was on tagging. U of Iceland researchers did collect some biopsy samples during other time periods.

CHRONOLOGICAL OUTCOME

15 June:	Conducted pressure tests in SMRU dive chamber
23 June:	Travel to Iceland. Arrived Heimaey, all OK
24 June:	Set up equipment in the lab. Car got a flat tyre, took some time to fix.
25 June:	continued equipment setup. Weather was ok and many whales were spotted from the shore station. So, we tried tagging for 3 hours with integrated Dtags. No attempts, but it was a good training experience. Equipment worked well.
26 June:	Bad weather. Ellen and team continued training and setup of equipment. Paul and Patrick setup antenna systems on the Fridrik with input from Erlendur.
27 June:	Bad weather. Finalized setup of Fridrik. Tag team continued training and setup of equipment, and preparation of Mixed-Dtag++.
28 June:	Bad weather. Ellen and team did harbour tests of goniometer system which worked well.
29 June:	Bad weather, but a large lee on the East side of the island allowed a boat-boat test of the goniometer system. Good test, but bad weather limited the range tested to ~5nm. Good locations were received on both systems.
30 June:	Good weather conditions. Tagged two killer whales with Mixed-Dtag++. Fridrik came out with playback team, and Goniometer tracking worked very well, with receptions from both tags and an outstanding number of locations from tag oo23_181b almost every 2 minutes as programmed, up to 5nm distance.
01 July:	Tag oo23_181b was still in the study area and goniometer location was made just 15 minutes after startup which guided us to the tagged group. One playback of two planned was done. Goniometer tracking (direct and locations) aided the playback very much. At 18:00 we had beeps from tag oo23_181b but no signal from tag oo23_181a monitoring from the shore station. Tag oo23_181b was recovered at 20:00. Had fish eggs on it.
02 July:	Tag oo23_181a was recovered, using the Fridrik, close to the area from which we'd received Argos locations 60km to the west of Heimaey. The tag was floating well, with the antenna out of the water.
03 July:	Weather was OK in the morning, and we tagged a whale very quickly – oo23_184a. It was a small animal in the same group as the final tag deployment in 2022. The tag was placed quite well at the bottom of the dorsal fin, good beeps and photographs – but no successful goniometer position, as the GPS did not get enough satellites. Fridrik came out by 14:00 for a playback and the crew change was accomplished. Visual tracking was difficult, and weather increasing, so we cancelled the playback.
04 July:	Tag oo23_184a fell off the whale early, beeps heard from shore station towards Surtsey at 10:30, matching the locations of Argos/GPS. Rough weather so we took the Fridrik. Something odd with VHF 148.120 as no signals were heard as we got closer to the tag, until we were very close. Tag recovered.
05 July:	Bad weather. Conducted a VHF test of all 3 units we have. 148.120 was weaker, with no signal heard at the shore station from the Fridrik, while 148.020 and 148.200 were equally audible. So, we changed the VHF to 148.020 and added heat shrink to the base of the VHF antenna.
06 July:	Attempted tagging for 6 hours,2 attempts, no success.
07 July:	Golli left at ~13:30, found whales near 3 fingers. Two tags deployed. Mixed Dtag attached to an adult male oo23_188a with good placement with antennas angled up, on the dorsal fin. Integrated Dtag went on a ~4-5 yr old calf nice

	placement just forward of the dorsal fin – oo23_188b. VHF check at evening 21:30 no beeps, both tags on. Many Argos and GPS-Argos showed animals still near 3-finger where they were tagged
08 July:	6am morning VHF had tag oo23_188b off, tag oo23_188a still on. Argos position was near 3-finger. Fridrik departed at 08:00 with Simmi as skipper. Tagged whale found easily near 3-finger, aided by realtime goniometer angles. Golli retrieved tag oo23_188b floating nearby – ARGOS antenna for integrated Dtag was in the water, explaining no Argos positions after tag off. 2 playbacks successfully conducted, and tag oo23_188a came off as programmed.
09 July:	Tag team is resting and catching up with preparations to tag tomorrow. GPS test on the shore station indicated a weaker performance for PTT 183277 than separate unit 215143. Swapped those GPS-Argos units.
10 July:	Went tagging near three fingers, with Paul for cross-training. Outstanding weather with lots of killer whales and at least 3 humpback whales. Mixed-Dtag was deployed almost immediately on a ~7rd old animal oo23_191a, and integrated Dtag a few hours later on a smaller ~3yr old whale. Integrated tag only attached with one or two suction cups but stayed on until we left the area in increasing winds. Tab oo23_191b was off on the evening VHF check from the shore station.
11 July:	Tag oo23_191a was off at the 7am VHF shore station check. Both tags were recovered in fairly high chop, sea state 4 conditions, low swell. Both tags were floating well.
12 July:	Paul tagged a humpback whale in an ideal position next to the dorsal fin mn23_193a. Fridrik left at 3pm for radio tracking, got GPS locations via Goniometer at 5.9nm on the way out, and then one at 5.4nm on the way back.
13 July:	Bad weather. Measured antenna heights to calculate line of sight to horizon. Base of Gonio and custom +5dB antennae were 4.24m and 5.09m, respectively. Humpback tag was recovered successfully. Some Argos locations were obtained during recovery.
14 July:	Bad weather due to high winds. Shore day.
15 July:	Tag team found long-finned pilot whales to the east and attached a mixed dtag to a smaller pilot whale, but tag came off after 30 minutes. Moved to 1-finger, and quickly tagged a humpback, but tag was attached through the water and the tag fell off early. Integrated Dtag attached to an adult female killer whale oo23_196a, made a clear popping sound indicating a good initial attachment.
16 July:	Tag oo23_196a was off by 8:30 VHF check. Team departed to recover it, then moved to pilot whales sighted in calmer conditions to the East. Three pilot whales were tagged, 1 with mixed-Dtag and twice with integrated Dtag. All the tags fell off early, and the whales were seen rolling a lot. All tags recovered and the team returned.
17 July:	Bad weather. Stayed on shore
18 July:	Windy weather. Shore day
19 July:	Last possible day for tagging. Fridrik was not available so no attempts made.
20 July:	Backed up all data and packed equipment
21 July:	3S team departed Westmann Islands

CORE UNIT PRESSURE TESTS PRIOR TO THE TRIAL

Two DTAG3 core units and two integrated-Dtags were received from U Michigan prior to the field trial, and were tested in a pressure chamber run by the SMRU Instrumentation group (thanks to Steven Balfour) on 15 June. All of the units registered depth changes normally, and did not have any apparent faults.

SUCTION CUP TAG DEPLOYMENTS

All tagging was conducted off the RHIB "Golli" (Fig 2) using a 5m hand pole with a straight orientation of the tag relative to the pole. As detailed in table I below, a total of 14 deployments were made with the Mixed-Dtag++ (N=9) or integrated-DTAG (N=5) system (Tables I and II). Tagging was carried out using a pole from the Golli (Fig. 3). Of the 14 tag attachments, no behavioural response to tagging were noted for 6 cases, a minor response (level 1), such as a body flinch or tail slap was observed for 6 cases.   Level 2 behavioural responses were observed in two cases. For deployment mn23_196a on a humpback whale, the animal did not immediately re-surface as expected and did a spyhop nearby, indicating a succession of minor responses. For deployment gm23_197a on a long-finned pilot whale, the tagged animal was observed making a series of corkscrew swimming motions, also classed as a succession of minor responses.

A total of 8 tags were deployed onto killer whales, 2 to humpback whales and 4 to long-finned pilot whales. All of the tags attached to pilot whales detached very soon after deployment (2.3hr maximum) apparently due to animal behaviour including inter-animal contact. Mixed-Dtag deployments with killer and humpback whales (N=7) had good retention times, with an average duration of 15.9 hrs, and a maximum deployment duration of 24.8 hrs. Integrated Dtag deployments with killer and humpback whales (N=3) had substantially shorter average retention of 8.4 hrs, and maximum of 13.5 hrs. For killer whales, tag deployments were generally longer, and more likely to last until the scheduled release time, when the tagged animal was an adult sized animal or larger juvenile (e.g. oo23_181a, oo23_181b, oo23_188a) whereas deployments on smaller animals (oo23_184a, oo23_191a) tended to be shorter and less likely to last until the programmed release time.

To increase the likelihood of deployments that last the full 24 hours needed for 3S4 sonar trial experiments, we therefore recommend to prioritize use of the Mixed-DTAG++ over the integrated-DTAG. We recommend to focus tagging efforts on adult animals – though that may reduce all tagging opportunities given smaller animals may surface near the tag boat.

Table I. Mixed-Dtag++ (m-dtag) and integrated DTAG (int-dtag) deployments during the 3S-2023 pilot study trial. All tags were deployed using a 5m long handpole. Resp is the scored behavioural response to tag attachment on a 0-3 point scale.

Date ID time	DTag start deployment location Video and LLdata start	Resp	Hrs on animal; Why off	Tag type Dtag ID PTT LL unit	A-argos Ga – GPS via ARGOS Gl –GPS log Animal;floating Rate per hour	Time off Recovery Date time location	On animal Gonio (received signals, succ/hr) Median gps delay	Playback Y-focal? Start times	Comments:
30.06.2023 oo23_181a 15:49	12:43:21 63.35827N 20.31958W LLd ~16:11	1: minor tail slap	24.8 progra m	m-dtag 326C 183279 23002	A 1.49; 0.08 Ga: 0.32; 0.04 Gl: 2.66; 1.89	16:35:36 02 July 18:05 63.3833 20.4334	Regular pos. (17.5, 9) 9 min	Y- focal 18:54:07 20:14:20	Good tagout low on dorsal fin. Sprouter male 2-3 beeps Argos aided 60km distant recovery
30.06.2023 oo23_181b 16:23	16:21:40 63.3513N 20.36107W LLd~11:54	0 no resp	24.0 progra m	m-Dtag 333C 183277 23003	A: 1.58; 0.93 Ga: 0.42; 0.83 Gl: 0.83; 4.95	16:22:31 01 July 20:00 63.389 20.364	4.9nm successes on 30 June. 01 July max 6nm (16.7, 13) 7 min	NONfoc al 30 06 as above next day focal 11:53:29	Very high centered just behind blow hole. Photos indicate it was a Sprouter male 2-4 beeps/surfacing 2nd pb cancelled
3.07.2023 oo23_184a 11:15	11:16:17 63.4011N 20.2548W LLd ~15:14	1 body twitch	10.6 hr off early Likely body contact as logger	mDtag 333C 183277 23003	A 1.35; 0.58 Ga: 0.19; 0.13 Gl: 1.64; 4.25	21:38:37 04 July 13:09 63.19893 20.44064	No successes, many due to not enough valid sats (Gps issue)	No – tracking started, but pb aborted due to high wind	Argos aided location. 1-2 beeps/surfacing VHF signal weak, later replaced after test. Juvenile sized animal

			moved				Bearing aided playback		
7.07.2023 oo23_188a 15:32	15:31:06 63.50498N 20.54168W LLd ~17:12	0 no resp	21.2 hours progra m	m-dtag 326c 183279 23002	A: 1.51; 4min Ga: 0.3 Gl: 2.22	12:41:31 08 July 12:45 63.4834 20.5501	Lots of successes 3.5nm max (17.7/7.7) 8 min	Yes- focal next day 10:15:30 11:36:51	Adult male – antenna up on lower dorsal fin. 2-4 beeps/surfacing
7.07.2023 oo23_188b 15:32	16:41:38 63.49113N 20.51852W No video	1 small tail slap	13.5 hr Off early likely due to body contact – many tag movem ents apparen t.	int-dtag D339 198611 No video	A: 0.52; 0 Ga: 0.22; 0 Gl: 1.48; 0.63	06:11:54 08 July 09:20 63.4889 20.5621	n/a Tag already off	n/a Tag already off	Quite small animal ~4-5 yr old Good location forward of dorsal fin 1-2 beeps/surfacing 3 hours floating. Bent antennas so Argos antenna was in the water.
10.07.2023 oo23_191a 12:15	12:15:37 63.48352N 20.53442W LLd ~16:45	0 no resp	11.9 hr Off early	m-dtag 326c 183279 23002	A: 0; 0 Ga: 0; 0 Gl: 0.76; 3.19	00:06:19 11 July 10:27 63.46092 20.34575	n/a	n/a	Small animal ~7yr old. Low left flank 0-1 beeps / surfacing

10.07.2023 oo23_191b 14:43	14:42:43 63.4053N 20.56047W No video	0 no resp	2.2 hr Off early.	int-dtag 347, floppy 213647 No video	A: 2.27; 1.22 Ga: 0; 0.11 Gl: 0; 2.66	16:55:52 11 July 11:44 63.50145 20.62043	n/a	n/a	very small animal ~2-3 yr old left flank, only 2 cups seems to have stuck. Tag wobbly. 1-2 beeps/surfacing
15.07.2023 oo23_196a 18:55	17:33:05 63.45592N 20.60603W No video	1 tail slap	9.4 hr Off early.	int-dtag D339 198611 No video	A: 0.95; 0.35 Ga: 0.24; 0 Gl: 3.68; 0.83	03:21:23 16 July 11:50 63.4926 20.57907	n/a	n/a	Adult female tag reasonably high right side below dorsal fin. GPS antenna still bent. 1-2 beeps/surfacing
12.07.2023 mn23_193a 13:04	13:03:06 63.47075N 20.6129W LLd 15:49	0 no resp	16 hr Off early.	m-dtag 326c 183279 23002	A: 0.94; 0.34 Ga: 0; 0 Gl: 0.19; 6.51	05:06:51 13 July 10:56 63.39678 20.64965	Used to approach whale max range 5.9 (8.5,8) 16 min	n/a	Large humpback whale, very good stick high on left side of dorsal fin. 4-5 beeps/surfacing
15.07.2023 mn23_196a 15:48	15:47:41 63.45687N 20.6066W LLd 16:54	2 – did not surfac es fully. spyho p after	2.8 hr Off early	m-dtag 326c 183279 23002	A: 0.72; 1.62 Ga: 0.36; 0 Gl: 1.08; 4.86 Floating 37 min	18:34:02 15 July 19:11 63.4614 20.60157	n/a	n/a	Large humpback whale, tagged through water, one set of beeps heard, but not after, tag may have slipped.
15.07.2023 gm23_196a	13:23:10 63.25152N	0 – no resp	0.4 hr Off	m-dtag 333c		13:49:40 15 July	n/a	n/a	Smallish animal. Tag slipped on

13:23	20.47953W LLd 17:30 (off whale)		early	215143 23003		13:23 63.25082 20.51718			tagging to left rear flank. 1-2 beeps/ surfacing.
16.07.2023 gm23_197a 12:54	12:54:44 63.35898N 20.27928W No video	2 – fast rollin g Corks crews after tagout	2.3 off early	int-dtag 347 213647 No video	A: 1.34; 1.34 Ga: 0; 0 Gl: 0; 0	15:08:02 16 July 16:06 63.33995 20.2789	n/a	n/a	Good attachment left side dorsal fin. Female size 3 beeps/surfacing. Limited gps due to being on the side?
16.07.2023 gm23_197b 17:08	17:08:26 63.30863N 20.2532W LLd 16:55	1 – contac t with boat after tagout	0.7 hr Off early	m-dtag 326c 183279 23002	Animal A: 0 Ga: 0 Gl: 0	17:48:46 16 July 17:58 63.30863 20.25328	n/a	n/a	Looks like male size. Left side below dorsal fin, antenna up. Short deployment could be reason for no Argos
16.07.2023 gm23_197c 17:39	17:01:24 63.31472N 20.2532W No video	1 – quick dive	0.2 hr off early	int-dtag 347 213647 No video		17:48:13 16 July 18:10 63.31877 20.2374	n/a	n/a	Low on the left flank. 0 beeps heard

Figure 2. Golli (left panel) was used for all tagging during the 2023 trial. Right panel shows tag placement of tag deployment mn23_193a attached to a humpback whale. Photo by Tatiana Marchon.

GPS LOGGING, GPS-ARGOS, AND GPS-GONIOMETER TRACKING

Performance of the LOTEK GPS receiver and ARGOS transmitter was similar to that of the 2021-22 baseline trials, with locations logged regularly for tag placements that weren't low on the body. We carefully quantified the rate of location information received while tags were attached to the animals, and during recovery (Table I, column 6).

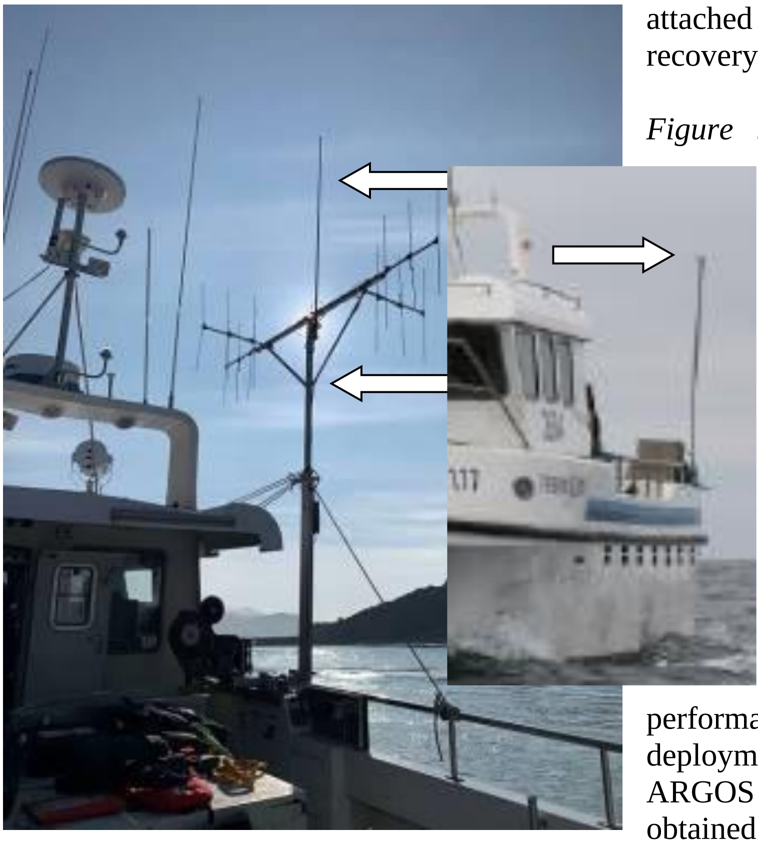


Figure 3. LEFT: The +5dB vertical antenna for receiving GPS-ARGOS transmissions was affixed to the Friðrik Jesson *(upper arrow). The base of the +5db antenna was 5.09m above sea level. The antenna signal was filtered in a conditioning box (lower arrow), before being sent to the Goniometer. RIGHT: A standard -2dB antenna was mounted on a pole near the stern with the base of the antenna 4.24m above sea level.*

ARGOS and GPS-Argos performance was quantified for 11 deployments which had a duration >1hr. ARGOS positional information was obtained for 10/11 deployments, with no locations received for one deployment that was low on the body (0-1 vhf beeps/surfacing). For the other 10 deployments, ARGOS positions were obtained at a rate of 0.7-2.2 locations/hr. GPS positions via ARGOS were less frequently obtained from 7/11 deployments at a rate of 0.2-0.4 positions/hr. Tag placement was important for ARGOS performance with best outcomes achieved for one deployment on the back between the blowhole and dorsal fin on a killer whale.

For GPS-Goniometer tracking of whale position, a custom "+5dB" Goniometer antenna was mounted on Friðrik Jesson (Fig 3). The signal from the Goniometer antenna was filtered in a custom conditioning box before being input to the Gonio2 goniometer. Data from the Gonio2 was input into a dedicated laptop computer where it was processed with custom software (‘realtime.exe’) provided by LOTEK. A U-Blox GPS receiver was also connected to the laptop computer, and used by the software to collect GPS satellite ephemeris data. The output of the LOTEK software was a standard set of GPS strings. We visualised the GPS locations of the tracked whales using openCPN chart plotting software, which was effective. However, for future efforts, development of a data visualization system similar to Logger would improve functionality.

One dedicated ship-ship test was successfully carried out early in the trial (29 June) and had successful locations out to 5nm, with roughly equal performance from both antenna types. This indicated that the reception system on the Fridrik was functioning well. Real-time GPS positions were received using the +5dB antenna, while the standard goniometer antenna was used to obtain real-time bearing to the animals.

Real-time whale-boat Goniometer GPS tracking of tagged whales from the Fridrik was conducted for 5 deployments (4 killer and 1 humpback whale; see Table I, column 8). Successful locations were received from the Goniometer system for 4 of the 5 deployments, with a consistency and reliability of successful performance not achieved in the 2021 or 2022 efforts. Reception rates for these 4 tags ranged from 8.5-17.7/hr with successful locations received at a rate of 7.7-13.0/hr. GPS positions were received with an average delay (time from GPS fix on animal to reception) of 7-16 minutes. Maximum ranges of successful receptions by whale were 3.5-5.9nm. The maximum distances that GPS positions were received with the goniometer system are consistent with line-of-sight distances to the horizon given the heights of the goniometer antennas (4-5m above sea level). If similar performance is achieved on the HU Sverdrup II with antennas placed substantially higher (20-25m), then we can predict successful GPS tracking at twice the distance achieved in the pilot study trial.

No Goniometer successes were received for a deployment on the side of a juvenile sized killer whale oo23_184a (Figure 4, below), and no successful GPS positions were logged during that deployment either. However, ARGOS-satellite locations were received at a rate of 1.3/hr. The primary reason no GPS positions were obtained for this animal was due to ‘not enough valid satellites’ reported by the LOTEK realtime tracking and logging software. This outcome indicates that the GPS reception system on the tag was not successful for this deployment, likely because the body of whale likely blocked GPS-signal reception on the GPS antenna which was relatively low on the body and somewhat downward oriented (see tag position in Figure 4).

Figure 4. Tag deployment oo23_184a which had no successful GPS positions received by the goniometer system (though faulty packets were received), nor were any GPS positions logged, despite a reasonable number of ARGOS receptions having been received.

In contrast to the poor performance of tag deployment oo23_184a, figure 5 below shows three of the best performing tag placements on killer whales. These strongly performing deployments for goniometer reception of GPS positions were those placed with vertical orientation of the antennas and/or higher orientation of the tag on the whales body. The three successful deployments were also for tags placed on larger animals – in this case adult males or juvenile males with the beginning of growth to their dorsal fin ('sprouter males').

These results indicate that placement of the tag on the side of the dorsal fin can be effective, particularly for larger animals if the tag is placed high – but the lack of GPS receptions for deployment oo23_184a indicates a risk that placements on the side of the dorsal fin can fail to obtain successful GPS positions. This is likely due to the body of the whale shielding the GPS antenna from much of the sky. Therefore, we recommend tags be placed flat on the body between the blowhole and dorsal fin, as for tag oo23_181b (Figure 1 & Figure 5, left panel). A 90-degree robot on a handpole is the best tagging system to place the tag in a controlled fashion on this part of the whale body.

Figure 5. The 3 well-performing tag placements for GPS-goniometer performance on killer whales. The best and most consistent performance was found for deployment oo23_181b (left) with the tag placed flat between the blowhole and dorsal fin. Excellent performance was achieved for oo23_188a (middle) with the antennas pointing up on a large male. Good performance was obtained for oo23_181a, which was a juvenile sprouting male, larger than animal oo23_184a (shown in Figure 4).

LITTLE LEONARDO VIDEO / DATA SENSOR PERFORMANCE

As shown in Figure 1 (right panel), a DVLW2000M130SW-4R video and data logger was integrated into the Mixed-Dtag+ system (named Mixed-Dtag++ when carrying the video logger). The loggers were custom built for the project by the company Little Leonardo based in Tokyo, Japan, and were specified to record 24 hours of depth and 3-axis accelerometer data as well as ~5-7 hours of video data (depending upon battery performance). The loggers are triggered manually, and that time has to be recorded by the user. The trigger time plus any programmed delay is stored as the "Video and LLdata start" time (column 2 in Table I).

Video and data recording was successful for all 9 mixed-Dtag++ deployments (Table I). Data records were consistently started at the specified start time, and recorded for 24 hours as designed.   The first file of the video recordings started at the specified time, and had a duration of 30 minutes. However, individual video files after the first file did not always start at the expected time and did not record for a consistent duration. The time stamp for each file was also not set to local time, though the relative timing of files from the 'date modified' column in windows explorer are consistent. Synchronization of the audio data recorded by the Dtag core unit and the video sequences recorded by the Little Leonardo DVLW2000M130SW-4R units will require care, and for shorter video recordings (with insufficient cues for synchronization), it may not be possible to make fully synchronized recordings. We have been in contact with the manufacturer to address these issues.

Video quality was consistently high in all of the recordings, and revealed details of feeding and social behaviour. However, initial inspection indicated that some video sequences were too dark to see details (eg. during deeper dives). The red LED flash was used for some deployments, but did not increase visibility sufficiently to counter the loss of ambient light at depth. Given the loss of recording time when the LED is used, the benefit to data quality from the use of the LED should be evaluated to decide whether or not to use the LED.

PLAYBACK OF NATURAL AND CONTROL SOUNDS TO KILLER WHALES

We conducted playback experiments with three tagged whales (Table II), which contained a primary test stimulus (natural sounds of calling long-finned pilot whales), and a control stimulus (broadband noise). Note the second stimulus for focal oo23_181b was not transmitted due to logistical constraints. Visual tracking and scoring of behaviour was carried out, alongside real-time tracking via the Goniometer-GPS system. The standard 3S design was used with the playback boat positioned ahead of the travelling killer whale, at an offset of 30-60° from their direction of travel.

Table II. Summary data for playback experiments conducted to tagged killer whales.

Date	*tag ID*	*Resight #*	*playback stimulus*	*UTC time at start of playback*	*UTC time at end of playback*	*playback boat position start*	*playback boat position end*
30/06/2023	oo23_181a	320	Noise 3 (2015-07-07)	18:54:07	19:09:08	N63°20.246 W020°28.952	N63°20.139 W020°28.732
30/06/2023	oo23_181a	320	PW 3 (gm21_187a/2015-07-07a)	20:14:20	20:29:20	N63°21.445 W020°32.514	N63°21.377 W020°32.253
01/07/2023	oo23_181b	321	PW 1 (2015_18_07d/e)	11:53:29	12:08:30	N63°22.001 W020°25.141	N63°22.081 W020°25.293
08/07/2023	oo23_188a	325	PW 3 (gm21_187a/2015-07-07a)	10:15:30	10:30:30	N63°29.196 W020°33.431	N63°29.171 W020°33.346
08/07/2023	oo23_188a	325	Noise 3 (2015-07-07)	11:36:51	11:51:51	N63°28.925 W020°32.341	N63°28.865 W020°32.237

The quality of data collected during the playback experiments was high, and all tag deployments contained GPS locations, to augment the visual tracking undertaken during each experiment period. In two cases (oo23_181b and oo23_188a), we conducted playback experiments the day after tags were attached. This was made possible by the long tag-attachment durations and regular real-time GPS positions provided by the goniometer to re-locate the focal whale.

APPENDIX I: Cruise plan published prior to conducting the trial.

Cruise Plan

3S-2023 Pilot Study Trial

June 24 –July 21, 2023

Patrick Miller, Cruise Leader; Filipa Samarra, Field Party Chief

The 3S-2023 pilot study trial is primarily funded by the US Living Marine Resources (LMR) and French DGA, with additional support from, Jules Verne, and RANNÍS.

PROJECT OBJECTIVE

The 3S (Sea Mammals, Sonar, Safety) 2023 pilot study trial will focus on improving methods to be used in a 3S4 full scale behavioural response study (BRS) proposed for 2023-25. The feasibility of these methods was demonstrated in the 3S-2021 and 2022 pilot study trials, while collecting valuable information on the target species killer (*Orcinus orca*), humpback (*Megaptera novaeangliae*), and long-finned pilot (*Globicephala melas*) whales. The proposed 3S4 study has the goal to quantify the responses of multiple simultaneously tagged whales to continuous active sonar (CAS) transmissions and aims at conducting long duration, controlled exposures (4-6h duration). This requires real-time location information of tagged individuals achieved with automatic relay of the tagged-whales' positions via the ARGOS satellite system and directly with a Goniometer antenna. In 2021 and 2022 baseline trials, the Mixed-Dtag+ system demonstrated effectiveness as the tag of choice for 3S4.

The overarching objective of the 2023 pilot study is to improve and demonstrate the capabilities of the Mixed-Dtag+ tag system with two key identified areas for improvement: 1) reception of tagged-whale locations via the ARGOS system and by Goniometer, and 2) establishing use of a new back-up video and data sensor produced by Little Leonardo to increase redundancy of primary data acquisition, and enable novel video observations of the tagged whales underwater behaviour and prey field near tagged whales. The tag system will be tested on study species to be addressed in the further full 3S4 study, and playback experiments of natural sounds will validate the functionality of the new tag systems to perform in 3S4 planned controlled exposure experiments. The effort will provide valuable baseline knowledge, including inter-specific interactions, of the study species.

CRUISE TASKS

The primary overall objective of this pilot study trial is to test and validate methodology intended to be used during the 3S4 full scale BRS trials proposed for 2023-25. Primary tasks have a higher priority than the secondary tasks. We will try to accomplish as many of the secondary tasks as possible, but they will be given a lower priority if they interfere with our ability to accomplish the primary tasks.

Primary tasks:

1. quantify and improve the functionality of GPS-ARGOS linked Mixed-Dtag++ and integrated Dtag3 to provide locations of tagged cetaceans via a) the ARGOS satellite system, and b) Goniometer reception of signals. The rate of reception, and delay involved, will be quantified and incrementally improved by optimizing software settings and hardware characteristics. Tests will be carried out with the vessel in dock and at sea, focusing on the whale-antenna distances over which the signals can be successfully received and decoded using the Goniometer system. Tags will be attached with hand poles. The killer whale is the primary species, but long-finned pilot and humpback whales may also be tagged.

2. deploy the Mixed-Dtag+ with the new Little Leonardo video-data sensor. Test release times >24 hr to establish maximum suction cup retention times.

3. conduct playback experiments with natural sounds (e.g. long-finned pilot whale sounds) to tagged killer whales, aided by locations provided by the GPS-ARGOS system. This will validate the functionality of the new tag systems to perform in controlled exposure experiments planned for the full 3S4 study. Visual surface observations will be collected before, during and after playbacks.

Secondary tasks:

4. Collect sightings and photographs of target species and other cetaceans encountered.

5. Collect echosounder survey data of herring in the study area, using a SIMRAD EK-80 echosounder system.

6. Collect biopsy samples of whales in the study area

MAIN LOGISTICAL COMPONENTS

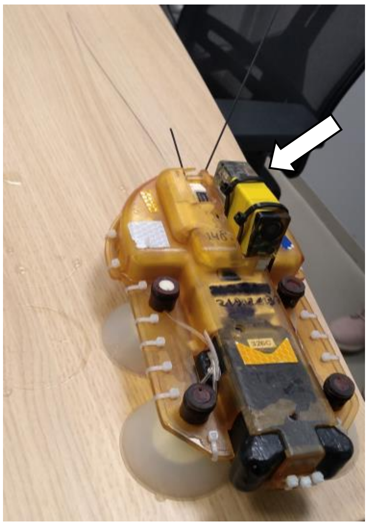
MV Friðrik Jesson

Skipper: Ragnar Þór
Mobile phone: +354-865-1895

Real-time GPS-ARGOS (CLS goniometer antennae), VHF (DFHorten system) and visual tracking. ARTS tagging platform if needed. Rough weather tag recovery. Length: 12m. Engine: Volvo 750 HP (diesel); 220V power Max/cruising speed: 17/13.0 knots

Vessel 2: Golli

Customized techno marine RHIB (http://www.technomarine.pl/) with Suzuki 200 HP 4-stroke outboard motor. This second vessel will serve as the primary platform to search for and tag whales, and as the source boat during playbacks experiments.

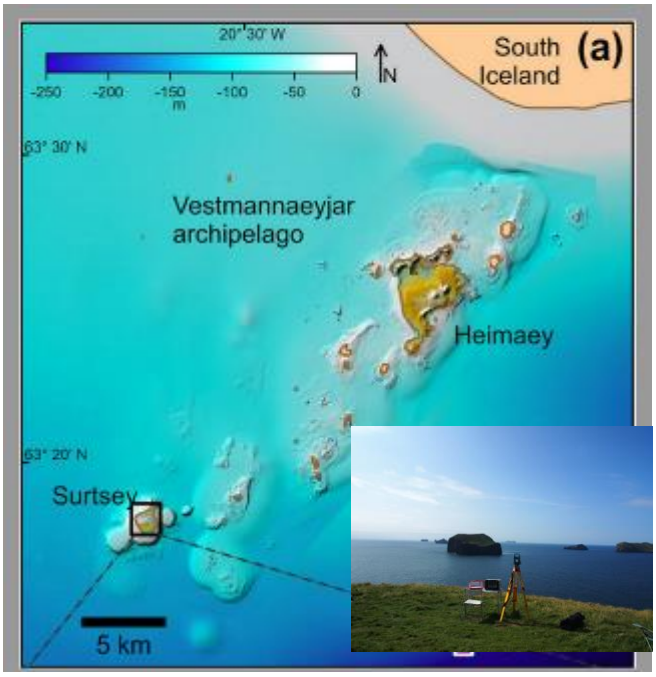


Mixed-Dtag++

3S-2023 will focus on deploying and demonstrating function of the Mixed-Dtag++, which is a suction-cup attached whale tag, attached using poles or ARTS launchers. Note this tag system uses Dtag2 suction cups. The tag systems will contain: Dtag3 core unit (audio, depth, 3-axis accelerometer, 3-axis magnetometer, programmable release); LOTEK integrated GPS-ARGOS logger; VHF transmitter, flotation. Three mixed-Dtag systems will be available, two with thinner 0.4mm Nitinol, and one with a thicker 0.7mm Nitinol ARGOS transmit antenna. A Little Leonardo video-data logger (provided by Dr Aoki at AORI, U of Tokyo) will be added to the Mixed-Dtag+ system.

Above is an image of the Mixed-Dtag++. Note the additional video logger attached to the upper-right portion of the tag (indicated by a white arrow).

In addition to two Mixed-Dtag++ units, two integrated Dtag3 systems (with LOTEK GPS-ARGOS) will be tested.



OPERATION AREA

The operation area will be the waters of the Westmann Islands, in southern Iceland. The area is a long-term field site, with large numbers of killer whales and other species sighted during the summer months. A shore-based sighting station near the southern tip of the main island will be used to visually locate animals, and to assess weather conditions. A science team under management of F. Samarra will run visual effort from the shore station.

Left: Map of the Westmann Islands archipelago. Inset: view from the landstation looking southwest over the Westmann Islands.

TRIAL SCHEDULE

22 June: Barluet arrive Keflavik with playback gear. Stay at hotel.
23 June: Miller, Bryson and Robinson, arrive Keflavik, pick up rental car and transit to Heimaey. Hayward will arrive separately to Heimaey. Barluet + playback gear transit to Heimaey. First night of lodging.
24-25 June: Prepare tags and test goniometer reception systems, prepare playback equipment
26 June: Start of full operations with whales.
27 June – 18 July: Regular operations.
19 July: Last possible day of full research operations. Tags recovered by end of day
20 July: Break down and pack equipment for shipment
21 July: Miller, Hayward, Bryson, Robinson and Barluet depart Westmann Islands, departing lodging. Return rental car. Stay in hotel near airport.
22 July: Miller, Hayward, Bryson, and Robinson flight to Edinburgh. Barluet + playback gear flight to Paris.

STUDY ANIMALS

The primary target species is killer whales, with secondary species long-finned, humpback, and minke whales expected to be available for study. Individuals of these target species will be chosen opportunistically from animals found in the study site.

SCIENCE CREW LIST / ROLES

NAME:	Primary Role	Secondary Role	Tertiary Role
Patrick Miller	Cruise leader	Tagger / Tag technician	Playback coordinator
Filipa Samarra	Field party chief	Land Station	Photo-id/biopsy
Paul Wensveen	Goniometer setup	GPS-ARGOS tracking	Tagger
Lucie Barluet de Beauchesne	Playback experiments (operator)	VHF and visual tracking	
Anna Selbmann	Visual observer	Playback experiments	Dtag technician
Tatiana Marchon	Photo-ID	Visual observer	
Barbara Neubarth	Golli boat driver		
Ellen Hayward	Tag technician	Goniometer tech	Shore station
Rebekah Bryson	Tag technician trainee	Goniometer trainee	Shore station
Heather Robinson	Tag technician trainee	Goniometer trainee	Shore station

DAILY WORK PLAN

A daily planning meeting with the Cruise Leader and Field Party Chief, at least, will be held each evening to determine the specific plan for the next 24 hours. Over the 24 days of possible at-sea operations (26 June - 19 July, inclusive), the Golli is budgeted for this project for 10 days, and Friðrik Jesson for 5 days. It is therefore expected that the Golli will operate on most good weather days. If weather is unusually good, we may add additional days of boat usage. The Friðrik Jesson will be used primarily to track tags using the Goniometer system, and for tracking to conduct playback experiments. GPS-ARGOS-Goniometer tracking (led by Hayward) should always be carried out whenever the Friðrik Jesson goes to sea.

Vessels will work at sea for a maximum of 8 hours each day, with Friðrik Jesson and Golli returning to dock each night. The research team will be responsible for their own meals.

Recovery of any previously-deployed tags will be given top priority to assure of safe recovery of the loggers.

Searching phase

The shore-station team will start by searching for whales at the start of each day. As much as possible, searching will be conducted first from the shore station and vessels will only be used once sightings of target species are confirmed, but Golli can also search independently. Shore teams will be trained in the use of VHF receivers to listen for tags, and determine the direction to floating detached tags.

Before and during the search phase, tags should be prepared so they are ready in 'grab and go' mode for use upon encountering animals. Tags will generally be programmed for 25 hour attachment duration and with a 'release by' time, so they will detach by late afternoon the next day. Details of release times will be agreed between the PI and Field Party Chief depending on weather forecasts and recovery vessel availability.

Tagging phase

Once a target species is encountered, we will observe and record the overall group characteristics and start taking identification photographs. If conditions allow, we will commence tagging effort. Tagging will be done from the Golli using poles. During approach, the driver should drive parallel to animals, driving as slowly as possible and approaching from the side. The photographer will take images of the animals, and document whether or not there is a calf within the group. The photographer should attempt to photograph the tagging operation. Neonates cannot be tagged.

In addition to assessing the success or failure of each tagging attempt, it is critical to document the response of the animal to the operation, following the 1-4 point scale below:

1 No reaction: whale continued to show the same behaviour as before the tagging attempt;
2 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
3 Moderate reaction: whale modified its behavior in a more forceful manner but gave no prolonged evidence of behavioral disturbance, e.g. tail slap, acceleration, and rapid dive;
4 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

The tagger should attempt to place the tag high on the back just under or near the dorsal fin. Tag attachments low on the body are not desirable as they preclude testing of the GPS-ARGOS system.

Once a tagging attempt is successful, a datasheet noting the information should be completed and attempts should then be made to deploy a second tag on a different individual. Data sheets for each deployment should be completed promptly to assure that no information is lost.

As much as possible during tagging efforts, the teams on the vessels should collect additional data for project goals, and collect fish prey samples. Once tagging effort is ceased, the tag boat can be used to conduct sound playbacks, or for secondary data collection, including identification photographs or biopsy samples.

Tracking and observation phase
Once a tag is deployed, the Friðrik Jesson should move to track the tagged whale using the real-time GPS-ARGOS system, supported by VHF tracking, while additional tagging is attempted. The Friðrik Jesson may intentionally move away from the tagged whale to test the distance over which real-time GPS-ARGOS receptions function. GPS-ARGOS-Goniometer tracking (led by Hayward) should be carried out whenever the Friðrik Jesson goes to sea.

Playback-experiment phase
Once a tag is deployed on a killer whale, and sufficient time remains in the workday, the decision can be made to conduct a playback experiment. The Golli should cease tagging effort and be outfitted with required playback equipment. Friðrik Jesson should move to track the tagged whale using the real-time GPS-ARGOS system, supported by visual and VHF tracking. Visual sightings will be stored in Logger. Following at least one hour of baseline data collection, and a half-hour of successful tracking, the Golli will be placed at a GPS waypoint to transmit sound playbacks while drifting. The waypoint will be determined by a playback coordinator on the Friðrik Jesson based upon the movement trajectory of the tagged killer whale. Two 15-minute playback periods should be conducted with at least 45-minutes between playbacks. At least 30 minutes of post-exposure tracking data should be collected after the final sound playback is completed.

As tags will be programmed to detach late afternoon the day after tagging, we may also prioritize to locate whales tagged the previous day to conduct a playback experiment.

Tag-recovery phases / data download and backup
Detached tags will be recovered using the VHF signal to approach the tag, followed by visual sighting of the floating tag. ARGOS receptions should be checked to locate detached tags floating at sea. A pole with a net will be set up for recovering floating tags from Friðrik Jesson, which will be used in rough weather conditions. Suction cups should be inspected for any sloughed skin before commencing data download and battery charge.

VHF frequencies of the deployed tags should be routinely checked to listen in case they come off the whale. Checks of ARGOS fixes can be made to help ascertain the position of the tagged whale. Once the tag detaches, it is expected that a larger number of higher-quality ARGOS fixes should be made, which should be used to guide the boat close enough to detect the floating tags using VHF.

All tag data must be checked that it has downloaded properly and has been backed upon on at least two different hard drives before it is deleted from the recording device.

MANAGEMENT AND CHAIN OF COMMAND
Operational issues
As much as possible, decisions will be made by consensus between the Cruise Leader and Field Party Chief.   Operational decisions such as decisions on sailing plan and crew dispositions are made by the Field Party Chief. Scientific decisions, e.g. which types of tags to deploy, and priorities of a secondary tagging effort versus conducting playbacks are made by the Cruise Leader, after seeking advice from the rest of the team and the skipper.

Safety issues

The skippers of Friðrik Jesson and Golli will make the final decisions on safety issues. Always remember: 'Safety First'!

TRIAL RISK ASSESSMENT

The Friðrik Jesson is fully equipped with all required safety equipment to conduct the operations within the study area. The University of St Andrews Health and Safety Office has created a safety risk assessment for the activities to be undertaken on board which must be understood and signed by all members of the science team and the skipper.

PERMITS

Appropriate permits for working with the target species in the study site have been obtained from the Marine and Freshwater Research Institute (Hafrannsóknastofnun), by Filipa Samarra.

ENVIRONMENTAL IMPACT AND RISK ASSESSMENT

Risk Inventory: The pilot trial will be conducted during June-July 2023. This is a time when many marine mammals are expected to be present in the study area, and other human users of the area may be present. Echosounders will operate independently from any tagged whales, so the effect of those acoustic transmissions is expected to be negligible. Other environmental impacts of the trial will primarily stem from usage of the research vessels within the study area, and the impact of our research activities on the study animals.

The impact of the research vessels on the environment will be mitigated by driving at optimal speeds to reduce fuel consumption, and use of standard procedures to strictly regulate the disposal of waste materials. The impact of our activities on marine mammals is expected to be minor, and consist only of short-term behavioural disturbance. The activities to be conducted in the study area have authorization from the Hafrannsóknastofnun, and have been ethically approved by the University of St Andrews Animal Welfare and Ethics Committee. Details of mitigation procedures to limit our impact on the study animals are detailed in the next section.

ANIMAL RESEARCH MITIGATION PROCEDURES

We have specified the following mitigation procedures to limit the potential impact of our research on the study animals.

The active echosounder will operate independently of tagged whales, and will not intentionally be used closer than 1km from a tagged whale. Time periods when echosounders were within 5km of tagged whales will be checked following the cruise to determine received levels of the echosounder at each tagged whale.

Close approach by vessels for tagging and biopsy sampling:

Approaches by the vessel will be made at minimal possible speed. We should not manoeuvre to stay within 10m of any individual whale for more than 10 minutes.

Behavioural response monitoring:

During each tagging or biopsy attempt, the reaction to the procedure will be carefully observed and recorded using the 4-pt scale used by Hooker et al., 2001.

1 No reaction: whale continued to show the same behaviour as before the procedure;

2 Low-level reaction: whale modified its behavior slightly, e.g. dived rapidly or flinched;
3 Moderate reaction: whale modified its behavior in a more forceful manner but gave no prolonged evidence of behavioral disturbance, e.g. tail slap, acceleration, and rapid dive;
4 Strong reaction: whale modified its behavior in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

If any animal in the group exhibits a level 4 response to a procedure, we will cease conducting that procedure, and cancel subsequent procedures in the study plan. For example, if a whale responds with a strong reaction during tagging, then no further tagging attempts, biopsy attempts, or playback experiments will be conducted with that animal.

TRIAL READINESS REVIEW
All equipment and materials required for the research effort have been obtained or are scheduled for delivery in time for the project start. The research team has been trained as necessary for the activities and procedures to be carried out during the trial.

TRAVEL AND ACCOMMODATION
The entire team will stay in Heimay, Westmann Islands in rented accommodation arranged by the Field Party Chief.

Travel will be either by car from Keflavik via ferry to Heimaey, or alternatively via bus and ferry. The team will have a rented vehicle available for moving equipment, shopping, and other movements on Heimaey.

EQUIPMENT PACKING FOR SHIPMENT AT THE END OF THE CRUISE

The bulk of research gear from St Andrews will be shipped under a CARNET, which will then be sent to Tromsø, Norway for the 3S4 trial. The same items shipped there, must be shipped out of Iceland after the end of the trial.

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FFI's mission
FFI is the prime institution responsible for defence related research in Norway. Its principal mission is to carry out research and development to meet the requirements of the Armed Forces. FFI has the role of chief adviser to the political and military leadership. In particular, the institute shall focus on aspects of the development in science and technology that can influence our security policy or defence planning.

FFI's vision
FFI turns knowledge and ideas into an efficient defence.

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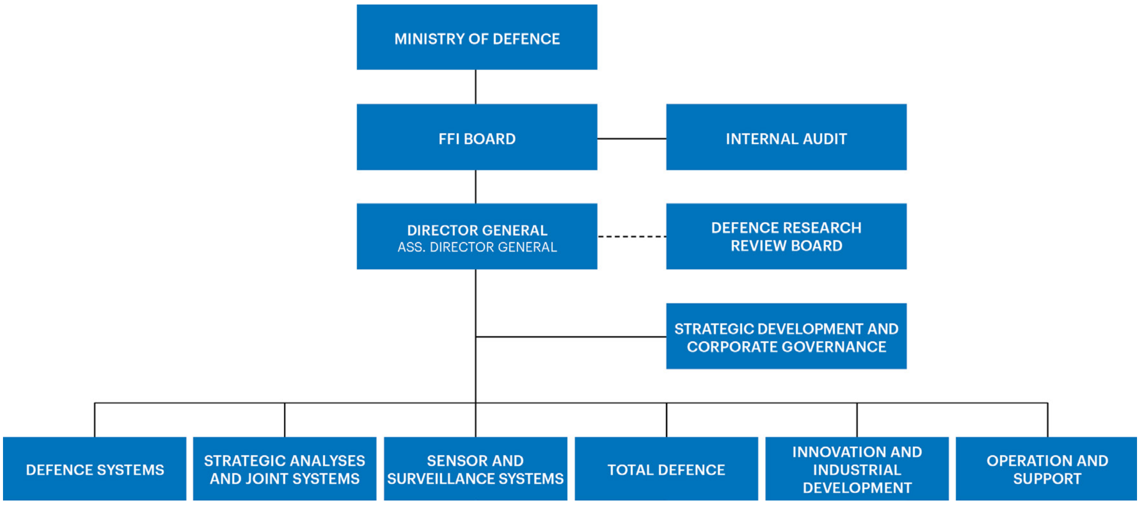
Creative, daring, broad-minded and responsible.



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